A LENGTHY TALE: THE DYNAMIC ANTHROZOOLOGICAL RELATIONSHIP BETWEEN HUMANS AND RATS

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ABSTRACT

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Title: A Lengthy Tale: The Dynamic Anthrozoological Relationship Between Humans and Rats

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Far from living in the shadows, rats figure prominently in our lives. Though we consider them wild animals, we most commonly encounter them in the city, the most human of the ecosystems. This point, among many others, presents one parallel between humans and rats: We both thrive in urban environments. People undoubtedly conjure images of filthy, malevolent creatures when prompted to think about rats. Even though rats indeed steal our food and have the potential to spread disease, pest animal is but one of the rat's triad of identities.

Alternatively, on top of this nettlesome role, rats serve a more didactic purpose. Scientists the world over exploit the convenience and customizability of rats to investigate biological phenomena, spanning topics such as psychology, physiology, and pharmacology. In this, we encounter yet another congruity of humans and rats, for the motivating assumption of rat-related research critically depends on it: Rats and humans are alike. If we believed anything else, conducting research on rats would be impractical.

Rats, unexpectedly, perform a more affectionate role as well. To those who are willing to forgive the rats their loaded past and symbolism, rats make excellent pets. While most of us try not to think about rats, pet rat—or fancy rat—owners achieve the opposite. The rat's capacity as companion animals perhaps best of all illustrates the human ability to simultaneously hold severely conflicting ideas in the mind about a single animal, for the animal possessing the stated three identities is one and the same.

I therefore seek in this thesis to examine the triple identity of the rat. I open with a discussion of rats in general, exploring some of the characteristics that define them. Additionally, I introduce the field of study dedicated to answering questions like mine: anthrozoology. In the next chapter, I review how rats act parasitically to human endeavors and what we've attempted in order to stop them. The following chapter relates the rats pervasive use in scientific research; I survey what makes rats the optimal animal model in the laboratory. I close the thesis with the rat's most surprising role as object of affection. Not only do many enjoy rats as companion animals—for reasons I explore in this chapter—but some non-Western cultures possess positive attitudes about rats in general. The overriding aim of this thesis is to get the reader thinking about rats.

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More immediately, I feel indebted to both my supervising professor, Dr. Janet M. Davis, and my second reader, Dr. David L. Gilden. I met with Dr. Davis several times a month. She always offered outstanding advice on what topics to focus on and suggested incredible resources that I cite many times throughout my thesis. Moreover, I'm grateful for the portions of our meetings spent discussing subjects wholly unrelated to my thesis, ranging from Fleetwood Mac to my plans for after college. (But I could probably find a way to connect these things to rats.) I always left my meetings with Dr. Davis feeling confident and eager to write. Dr. Gilden's primary wish for my thesis was that I be passionate about what I'm writing. This simple wish had far-reaching effects, ensuring that I always in fact liked what I was writing. If I couldn't think about my topic with enthusiasm, then readers would likely not find my writing compelling.

Finally, I need to thank the inspiration for this thesis: Lafayette and Chester, my two pet fancy rats. These guys surely didn't offer any content or style advice in my writing, but they nonetheless did something great. Lafayette and Chester provided me firsthand experience that there is more than meets the eye with animals in general and rats in particular.

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Introduction

Our relationship with animals is fraught. In one case, the city of New York expends inordinate resources in trying to eliminate one of its most common animals. Over one hundred mayors have tried unsuccessfully to curb this animal's occupation of the city, with one of the more recent bouts costing $2.9 million (Flegenheimer, 2015). Nonetheless, this animal continues to multiply unchecked, always outfoxing the traps and poisons deployed against it. Meanwhile, a vastly different relationship with animals unfolds: Scientists are edging closer to the total restoration of patients who have lost the ability to use their legs after spinal cord injury, all thanks to a striking Swiss research regimen tested on an animal long regarded as the paradigmatic laboratory model (Carey, 2012). Finally, a more affectionate bond emerges. A handful of Western areas are seeing a surge in a certain animal's adoption as a pet—one that cleans itself, doesn't bite, and can even learn some tricks (Surico, 2017). All the above accounts derive from articles in The *New York Times* published in the past decade, denoting that these relationships are one society's differential interactions with animals in a small window of time. Moreover, of course, it is a single animal that embraces all three of these identities: the rat.

Anthrozoology

It would be imprudent to scamper into the world of rats before first giving an overview of the field of study which permits this close inspection of human-animal relations. A relatively novel academic field, anthrozoology endeavors to analyze the interactions we engage in with other species (Herzog, 2011). Hal Herzog, a pioneering anthrozoologist, continues to document some peculiar examples of human-animal relationships:

> …how caring for chronically ill pets affects the quality of lives of their owners; the effect of pet ownership on surviving a heart attack; how children decide whether a strange dog is friendly or dangerous; sex differences in cat behavior…and the existence of morality in non-human species. (p. 16)

Giving merely a little thought to the matter reveals the influential role other species have in human lives. Despite the growing schism between humanity and nature, our visceral connection to other species arguably remains strong.

Anthrozoologists must take care not to fall victim to a most attractive pitfall in studying animals: anthropomorphism. When we anthropomorphize—and it's something most of us do—we project our human beliefs, emotions, capabilities, motivations, and desires onto other species. Granted, it's entirely possible that some other species are indeed capable of sharing some traits with humans. But we can never know what, in actuality, goes on in the mind of an entirely different species from ourselves. This caveat means that anthrozoologists must be cautious of what inferences they draw about other species based on their observations. While we earnestly want to describe our dog's emotion after getting caught making a mess as remorseful, the truth is probably unattainable. Be that as it may, Lambert (2011) implores that we not fear anthropomorphism excessively. This would lead to, as she credits to a philosopher friend, anthropodenial. We must strike a precarious balance in between the two poles.

Anthrozoology is the product of a menagerie of academic fields and their practitioners: psychologists, philosophers, behavioral neuroscientists, veterinarians, historians, and anthropologists. This integration of disciplines allows anthrozoologists to explore every aspect of human-animal relationships. Mindful of the conglomerate of fields required to adequately study anthrozoology, this thesis combines a number of analytical approaches to achieve its mission of

reporting the varied relations between humans and rats. As a result, some sections lean more historical while others more scientific; no one field could satisfactorily detail the unique interplay between us and them.

Pioneering rats

Scientifically, rats go by many names. The two principal species, the black and the brown rat, are *Rattus rattus* and *Rattus norvegicus*, classified under the most prolific taxonomic mammalian order, Rodentia (Iwaniuk, 2005). A closer inspection of the word Rodentia—specifically its second syllable—explains what feature distinguishes this group of animals: their teeth. And that dovetails with the popular conception of rats and their relentlessly growing two front incisors.

While a tremendous number of species can correctly be called rat, the two species stated above are the most consequential and proximate to us. In other words, if we were to run into a rat on the streets, it would almost certainly be a brown or a black rat—though the colors in their common names tend to deceive more than identify. In common parlance, these rats answer to many names. *R. norvegicus*, the more successful of the two species, goes by the following:

> the earth rat, the roving rat, the barn rat, the field rat, the migratory rat, the house rat, the sewer rat, the water rat, the wharf rat, the alley rat, the gray rat, the brown rat, and the common rat. (Sullivan, 2005, p. 5)

From the Latin, one could deduce that the brown rat (its usual name) is also the Norway rat, but this is a flagrant misnomer to be discussed later. The wide array of names attests to this rat's

prominence in our lives. Illustratively, brown rats predominate as the researcher's gold standard in the lab and the rodent owner's pet of choice in the home.

The smaller and more docile of the two species, black rats have been identified as the rat species serving as the vehicle for the spread of plague (Byrne, 2012). For most communities, though, black rats are not the rat species infiltrating the city—that's the province of brown rats. Black rats similarly boast a long series of names, the most common of which is the roof rat (Hendrickson, 1999). If these names have any authenticity, it isn't hard to imagine a house with a colony of black rats above and one of brown rats (see sewer rat) below, bookends for the unsuspecting family in the middle.

Rats evolved alongside humankind for much of their history, but they didn't start out this way. To find the birthplace of rats in the world, one would need to travel to the Central Asian temperate zone around present-day Russia, China, and Mongolia (Lindsey & Baker, 2005). Analogous to dogs, it did not take the first rats long to discover life was better alongside human beings; conversely, the rats established this relationship without the consent of our ancestors. At some point and by chance, rats began to associate humans with the presence of food—reliable and abundant food. Once rats made this mental connection, their spread across the globe proved an evolutionary blink of an eye. Thus began the coevolution of rats and humans. Rats began to occupy a new ecological niche tethered to human civilization. In all human migrations, whether as a result of war, trade, famine, or exploration, rats trailed swiftly behind (Hendrickson, 1999). In this manner rats radiated outwards from their origins in Asia.

The advent of seafaring ships tipped the scale in rat locomotion. As soon as rats could exploit this transport system, which was infinitely more efficient and rapid than the typical scurrying motion associated with them, their numbers and reach amplified immensely. Imitating

their imperialist human counterparts, rats began to colonize the world, landing in the New World before long, in the mid-eighteenth century. The black rats led the way, with brown rats gradually displacing them over time in the temperate regions (Hendrickson, 1999).

The arrival of the first black rats to Europe probably coincides with the Crusades. The bustling human activity in the European continent allowed the rat's quick domination of the land. Shortly after, these rats left their indelible mark on society with the Black Death. Brown rats migrated west a couple of centuries after this largest human cataclysm. By ship—sensing the vast food stores accumulated for long journeys—brown rats eventually reached England, whose maritime predilection accelerated the rat's global inhabitance (Galef, 2010). The popular name of Norway rat—propagated by an Englishman—to describe the brown rat is a misnomer, deriving from an erroneous account of these rats first coming to England on Norwegian lumber ships (Galef, 2010). In truth, several decades would elapse after rats first colonized England before they first set foot in Norway. Though the same rat, an iota of national rivalry seems to have slipped into its classification.

Characteristics

Animals come and go as evolution marches on. Natural selection has become a more hostile check on animal survivability as the human race spreads through the world and changes it to their liking. The rat, however, has always been one step ahead of these changes, unwilling to yield as have others before them. This owes chiefly to two characteristics: adaptability and avarice. These two qualities will crop up time after time as a sort of motif in the following pages. These rodents have made themselves masters of their environments. And if anything were to

change in their surroundings, they'd soon master that, too. Moreover, rats consistently exhibit the deadly sin of gluttony. Adept scavengers, rats will always find food—especially in our garbage-ridden cities, hence the rat's urban preference.

Like us, rats are omnivores, consuming a wide variety of both meats and vegetables (Barnett, 1975). In fact, rats would flourish eating virtually the same foods that we sustain ourselves on, and unlike many unruly children, rats are not picky eaters, their diets ranging from hard grains (hence the seemingly invincible teeth) and cabbage to freshly hunted fish (they're proficient swimmers) and freshly stolen bird eggs (Barnett, 2001). Though roughly sharing the same diet as us, rat teeth radically exceed ours in hardness. We could not imagine chewing through hard metals or even softer materials like wood, but these materials—and electrical wires, many of which fall prey to rats every year—are no obstacle to the rat; their two front incisors are inconceivably tough and sharp (Sullivan, 2005).

A cluster of traits enables the rapid multiplication of rat populations. Their sexual promiscuity and fecundity perplex us. Hendrickson (1999) catalogs this bundle:

> Female house rats are theoretically able to bear about sixteen litters a year, as their pups are born in about twenty-two days and they can mate again within forty-eight hours after having delivered them. Rats breed all year round. (p. 71)

Conservative estimates predict that a single pair of rats, after producing a litter of nine pups ten weeks into a given year, can multiply into 270 pups by the third month; this proceeds until the count reaches 11,907 rats by the end of the year (Marris, 2019). For those that know about the rat's sexual profligacy, it may be one of their more harrowing features.

In the same vein, rat families establish their households in intricate burrow systems underground (Barnett, 2005). For the most part, the modern city's concrete walkways preclude rats from their instinctive burrowing. Perhaps unwilling to deviate from their subterranean tendencies, rats flocked to the sewers. Nevertheless, alleys provide a remarkable breeding and feeding ground for rats (Sullivan, 2005). Nestled in between an array of restaurants, the alleyway can be an excellent purveyor of food for rats. Regardless, rats still need a place to call home, and they usually refuse to live aboveground, unprotected from potential predators. Despite the concrete pavement, provided rats can locate a hole at least a couple of inches wide, they can make their nest underground—rats can fit inside any opening the size of their head since it's the widest part of their body (Sullivan, 2005). Once underground, the tunnel broadens into interconnected dens where rats can make their living and store food, filling the den with soft materials as bedding (Barnett, 2005). Though this material tends to be innocuous, like straw and paper, Hendrickson recounts a particularly devious, yet unwitting, act of the rats:

> Detectives investigating the robbery of a New York City A&P grocery store in 1932 never smelled a real rat….$104 was missing from the previous evening's receipts….two assistants indignantly asserted their innocence….beneath the floor were five baby rats bedded down in $90 in currency and breakfasting on the $14 remaining. (p. 29)

Stories like this only contribute to the suspicion most of us direct toward rats. Additionally, thanks to its belowground location, many rats call the subway system their home.

Socially, rats exhibit a firm dominance hierarchy, characterized by alphas, betas, and omegas, the roles determined by size, aggression, and the outcome of attacks (Barnett, 2005). The alphas have the most liberty within a society and receive the lion's share of the food. Betas still thrive but answer to the alphas and receive smaller portions of food and only have access to

mates after the alphas have had their turn. Omegas represent the rat social class that lives paycheck to paycheck, hardly attaining enough food to survive.

Not all social interactions among rats are so classist. They're mostly peaceful in fact (Barnett, 2001). The most common rat interactions involve them grooming one another and sleeping together (Galef, 2010). Together, they defend the colony from any invading predators, like cats and rats from different colonies. Furthermore, one interesting manifestation of rat learning occurs in the context of society. Rats display a form of social learning in establishing preferences and aversions for different foods (Galef, 2010). Utilizing their acute sense of smell, rats discern what another rat had for lunch. Based on subsequent behavior of the postprandial rat, the learning rat will resolve either to search for or avoid that food (Barnett, 2001).

Perceptually, rats lag behind us in vision; they leave us in the dirt, however, in olfactory acuity. In observing a rat for the briefest of intervals, one would quickly notice the rat relentlessly sniffing the air around itself, gaining profound information about the external world in the process (Barnett, 1975). "Adult rats deposit scent marks in the environment that allows others to identify their age, sex, reproductive state, and dominance status" (Galef, 2010, p. 576). Moreover, rats hear in the ultrasonic range in addition to the higher end of the human auditory spectrum (Galef, 2010). Much of their communication, too, occurs in this range; some researchers have, in fact, investigated the production of rat laughter occurring around 50 kHz (Panksepp, 2007). Regarding taste, rats seem to prefer approximately the same foods that we do; rat taste sensitivity far eclipses our own, though. It's been reported that rats can detect vanishingly small amounts of poison in food, down to one part per million (Sullivan, 2005). This renders the exterminator's job exceedingly difficult.

An abundance of authors considers the rat a useful literary device. They can denote abandon, gluttony, decay, grime, and malice. Some people have a pathological fear of rats; think of Winston Smith, the protagonist of Orwell's *1984*. Unconscionable sums of money, consequently, have been funneled into ridding desirable areas of these undesirable beings. Unfortunately, it all seems like a squandering of resources; humans have been trying to eradicate these rodents from their lives for centuries and it appears we have nothing to show for it. To be discussed at length in the following chapter, rats, too, unwittingly serve as the vector for many a disease, eliciting even more ire from the masses and more seemingly futile attempts to stop them.

At the same time, rats have unintentionally helped us. Scientists have performed a litany of experiments on rats as their model for human physiology and behavior. Through the rat's sacrifice, we've collected a wealth of information about the world and ourselves that arguably would have been impossible, or at least prohibitively difficult, to obtain through other means. Simultaneously, rats inspire warmth and affection in a select few. Owning small mammals as pets is no recent practice. Though most regard hamsters and gerbils as cuter, rats possess several distinctive attributes that make them a sincerely unique pet.

I therefore seek to explain in this thesis this triple identity of the rat in the context of human life. In the first chapter, I begin with their darker side, analyzing why we channel so much revulsion and indignation at the small animal. Unmistakably, their interests do collide with ours: They serve as carriers of disease and burglars of food. Accordingly, I recount one of the rat's largest impacts on humanity in the Black Death, their toll on our food stores, and our typically misguided attempts to stamp out the destruction they cause. Their presence in the entirely human-made confines of the city remind us that we don't truly have full control of our world. In the next chapter, I explore their popularity in the laboratory, detailing the general purpose of

animals in scientific discovery, how the rat meets the criteria for animal model, how rats compare to *Homo sapiens*, and some common ways that researchers learn from the rats in their labs. In the final chapter, I delve into the rat's seemingly contradictory role as a companion animal. I delineate the origins of the first pet rats and what might draw a human to a rat in such an unlikely friendship. I close the chapter with examples of other positive relations that some cultures have with rats.

The simultaneity of these identities, although perplexing, is not impossible. Rather, which one predominates at a given moment is a function of our own attitudes and motivations along with the setting in which the interaction occurs. We seek to understand our world in precise terms. Our relationship with animals, in general, proves that this is challenging. At times, just as different animals occupy different ecological niches in the wild, one animal can occupy different human niches. Clearly, the rat is one such animal. In the abstract, I intend to examine the discordance in the ways we relate to animals and what may cause the discrepancy. To accomplish this, I use the rat as a prototype to explore a specific instance of one such apparently contradictory relationship with an animal. The ubiquity of rats in human-populated areas is hard to refute, making them an apt model for anthrozoological pursuit. Once we begin to pay even the slightest attention, we discover the omnipresence of rats in our lives and, despite our adamant desire to believe the contrary, we learn that rats and humans are not so different.

Chapter 1: Plagued by Abundance

The walls of the home are not impregnable. The majority of people live in buildings with defenses less indomitable than those of a medieval castle. By extension, sometimes our shoddy (in comparison) walls are breached. Today, though, we are not so concerned with repelling invading armies from our home. Rather, we contend with invading pests of different species: ants, bed bugs, cockroaches, and scores of other insects. Reigning high above these insects, though, is a rodent.

Everybody has a rat story. Indeed, many of the authors who came before me discovered the very same (Barnett, 2001; Hendrickson, 1999; Langton, 2007; Sullivan, 2005). In the countless times I have broached the subject matter of my thesis in front of others, seemingly everybody has an idiosyncratic anecdote to share about rats. To illustrate, one acquaintance of mine, upon hearing my topic, was beyond eager to explain her own strange encounters of the rodent kind. She recounted that, a while back, she noticed sounds of something scampering in her home. Inferring from her experience and geographic location, she believed the source to be rats. Surely enough, the sight of a rat in the flesh, a rare event as they are exceptionally stealthy, vindicated her. Predictably, she called her local pest control to manage the problem. After all, rats belong outside, not in the house. Pest control quoted her their price but—much to my acquaintance's dismay—said their methods are lethal. It's difficult to make sense of it, but this was intolerable for her. She subsequently attempted to resolve the issue herself. With nonlethal traps easily available nearby, she trapped several rats inside and released them outside. Despite the apparent success, my acquaintance knew that one rat seen foretold many unseen. In light of this, she again phoned the pest control company for some advice. Instead of tips on how to

eliminate her rat problem, she was met with a job offer after disclosing the number of rats she had caught.

Although anecdotal, the above account reflects a popularly held sentiment about rats: Americans don't want those vile creatures in their homes but don't want to be responsible for killing them, either. This is evidence of the complicated relationship of humans and rats. Most would swiftly respond that rats are unwelcome in their home. Yet some would hesitate to resort to any fatal measures in kicking the rats out, perhaps fearing that choosing to kill clouds the separation between rats and humans. The desire to evict any invading rats from the home mirrors a more general attitude towards nature, that the wild belongs outside and the tamed belongs inside. We arbitrarily divide the land between the *ours* and *theirs*, *here* and *there, synthetic* and *natural*. Nature forms part of the *there,* a place we can elect to visit on our own terms. We balk, however, when nature crosses these artificial boundaries. If a rat crosses the threshold into the home, we ought to restore order.

With this in mind, it is the aim of this chapter to discuss the first and most ubiquitous role of rats in the lives of humans: the role of pest. To begin, I recount the rat's part in one of history's most harrowing catastrophes, the Black Death. Next, I examine how the rat's large appetite proves destructive to human affairs. Finally, I explore the mostly unsuccessful attempts at rat extermination. Pests are organisms that prove damaging to human interests in some manifestation, whether that be to our health, cleanliness, property, or food ("Pest," n.d.). Rats undoubtedly wreak staggering amounts of damage on human interests. One example each in the domains of economics and health will serve to demonstrate the impact rats have on us. Rats inflict nearly a billion dollars in property damage every year in the United States (Wundram & Ruback, 1986). This destruction is untenable in light of the United States' tight budget,

explaining some of our most valiant and sometimes gratuitous efforts to control rat populations. Moreover, people fear the rat's capacity to spread disease. Plague is the quintessential example of rat-borne illness, but typhus is unquestionably more pertinent to people of today. Typhus, as spread by rats, has exterminated large swaths of human life. Notably, typhus is partly responsible for staving off Napoleon's invasion of Russia in 1812 (Hendrickson, 1999). Clearly, rats have affected the course of history.

A disease that knows no boundaries

It's virtually impossible to even consider rats without conjuring memories of their most macabre legacy: the Black Death. The impact of the rat's role in this pandemic is supported by our unceasing consciousness of an event which happened centuries ago, in the middle of the fourteenth century to be precise (Sullivan, 2005). As the devastation unleashed by the Black Death was unprecedented and persists today in shaping people's attitudes towards rats, an account of this agent of chaos is in order.

Bubonic plague is the chief variant known today; it's the one which caused upheaval across the Eurasian continent in the fourteenth century. Its name derives from its foremost symptom: the buboes (Ziegler, 1997). These buboes (or boils) are swollen lymph nodes, principally occurring in the armpits and groin. Boccaccio (2013) said the following of the symptoms in *The Decameron:*

> …certain swellings would develop in the groin or under the armpits, some of which would grow like an ordinary apple and others like an egg, some larger and some smaller….within a brief space of time, these deadly… [swellings]… would begin to

> spread from the two areas already mentioned and would appear at random over the rest of the body. (p. 5)

Boccaccio proceeds to note the later appearance of dark splotches on several areas of the victim's body. He plaintively concludes that these last symptoms portended unquestionable death.

In addition to this most popular version of plague, two other variants have afflicted humans. The first, septicemic plague, is surprisingly more virulent than bubonic plague (Hendrickson, 1999). Whereas bubonic plague resides predominantly in the infected person's lymph nodes, septicemic plague circumvents the body's lymphatic system; it is a disease of the blood. Hauntingly, while bubonic plague's time scale of death is measured with days, septicemic plague's is measured with hours. The final form of plague is pneumonic (Hendrickson, 1999). Plague develops into its pneumonic iteration when it invades the sufferer's lungs. Since the responsible pathogen can now exit the body through coughing or sneezing, this manifestation of plague is the most contagious of all.

The causative agent for every type of plague described above is a bacterium (Kelly, 2005). *Yersinia pestis* is its name. In some instances, names can contain immense information, and *Y. pestis* is no exception. Although plague has dealt numerous mortal blows throughout history, it was not until the close of the nineteenth century that the mystery mechanism of how plague spread would begin to unravel (Kelly, 2005). In 1894, Swiss pathologist Alexander Yersin—a student of germ theory pioneer Louis Pasteur—was the first person to identify *Y. pestis* as the culprit of the Black Death. Yersin was deployed to Hong Kong in the midst of their own plague outbreak in order to elucidate the workings of the relentless disease. Nearly

simultaneously, Japanese researcher Shibasaburo Kitasato—student of another germ theory pioneer Robert Koch—investigated the culpable bacterium.

The scientists' receptions in Honk Kong were markedly dissimilar, though. Being of slightly more global renown (and writing in English as opposed to French), Kitasato found a warm welcome in Hong Kong as he was provided spacious quarters in which to live and a well-equipped laboratory in which to probe the nature of plague (Byrne, 2012). Yersin, however, was left to his own devices. Denied plague corpses for study, Yersin relied on Italian missionary volunteers to unveil the secrets of plague. In time, Yersin gained access to the morgue, but only after successfully bribing a couple of English soldiers for admission (Sullivan, 2005). Byrne (2012) reports that Yersin grew curious of the buboes—the swollen lymph nodes characteristic of bubonic plague—on the cadavers. Conjecturing that these buboes might be teeming with the plague agent, Yersin searched here for answers. Not long after, Yersin discovered the rod-shaped bacterium responsible for a history of devastation, *Y. pestis*. Despite implicating the culprit bacterium, there was still a missing link.

Now, the causative bacterium was known. But the transmission of this bacterium was still unclear. Here is where the central player of this thesis, the rat, returns. According to Sullivan (2005), Yersin observed that rats played a part in the transmission of plague but could not entirely describe their position. French medical scientist Paul-Louis Simond completed the mechanism. Simond, researching plague in India, was inundated with evidence that rats must be involved in the life cycle of the plague bacillus (Sullivan, 2005). Other field researchers apprised him of the high volume of dead rat bodies they found near plague centers. It appeared that rats, too, suffered from plague. In fact, plague is a rat disease; it just happens to be able to jump to humans from time to time, a characteristic of a zoonotic disease. In addition, Simond noticed that

many factory workers succumbed to plague after cleaning up dead rats (Sullivan, 2005). This accumulated rat knowledge led Simond to conclude that something must mediate the transmission of disease between rat and human.

After bacillus and rat, Simond discovered one more piece of the puzzle: the flea. Certain fleas, *Xenopsylla cheopis*, among them, are the veritable transmitters of plague (Byrne, 2012). This is the organism that bridges the gap between rat and human infection. Naturally, these fleas feast on rats; specifically, they dine on blood, and they do this by piercing their host's skin with a proboscis. This appendage is a sort of two-way highway. On one hand, the flea draws blood through its proboscis. On the other hand, if the flea is full and has no more space for blood, it regurgitates the contents of its stomach through the very same proboscis. It is the combination of these functions which enable the flea to spread plague. To illustrate, should the flea already be infected, it will inject the bacteria into the rat upon feeding, thus infecting the rat. Alternatively, if a disease-free flea dines on a diseased rat, the flea will become infected. From here, it's possible to extrapolate how *Y. pestis* thrives as a pathogen. Unfortunately, when rats die off from plague, coupled with the rats' proximity to human civilization, the fleas will settle for human blood, bounding from rat to human, thus fomenting human plague epidemics.

Of course, this constellation of factors—rat, germ, and flea— which caused plague and enabled it to spread, was unknown to most victims of plague; the brunt of plague's impact on humanity hit in the middle of the fourteenth century, and these insights weren't reached until the end of the nineteenth century, leaving a multi-century chasm of confusion and disorientation over what was decimating the Eurasian population.

Pandemics in history

The Black Death might be the most prominent instance of rat-borne plague, but it is not the only one. Plague is a historic disease, likely in and out of contact with humanity for as long as we've existed. The first purported outbreak of plague was biblical; when the Philistines stole the Ark of the Covenant from the Israelites, God—as is his wont—punished the thieves with pestilence (1 Samuel 5:6 New International Version). The precise nature of the affliction is surmised to be plague: "…he brought devastation on them and afflicted them with tumors…and rats appeared in their land, and there was death and destruction throughout the city" (1 Samuel 5:6). Although the writers of the Bible didn't provide ample detail in describing other biblical epidemics unleashed by God, one can assume that many of these outbreaks might also have been plague.

Plague transcends the Bible in scope. Historically, there have been three plague pandemics (Hendrickson, 1999). (Pandemics differ from epidemics in geographic scope; a pandemic defies geographic boundaries.) The Black Death is the most infamous of the pandemics, but preceding it is the Plague of Justinian (Kelly, 2005). The Plague of Justinian exemplifies a common motif in the spread of disease: mobility. The easier it is for disease-carriers—rats—to migrate from place to place, the quicker and farther a disease can spread. As will recur with the rise and dissemination of the Black Death, commerce is partly to blame for the destruction. As commerce among distant regions becomes more extensive, these regions become more interwoven. The advent of new land and sea routes renders possible long-distance travel for humans. By the same token, travel became easier for plague-laden rats, never far behind humanity in their spread across the globe. Ironically, humankind's attempts to consolidate civilization through war and trade engendered the highly connected world ripe for pandemic.

Commencing in the sixth century, the Plague of Justinian swept through the Byzantine Empire, leaving mounds of corpses in its wake (Byrne, 2012). Without Roman cadavers for modern pathologists to analyze for signs of plague, we are left to comb contemporary accounts of the disease by scholars, doctors, historians, and their fellow literate ilk. From these records, it is clear that the infection was one of plague. Estimating historical death tolls is demanding work, but historians believe that approximately 30% of the world succumbed to this pandemic, which began during the reign of Justinian. Considering the overwhelming proportion of lives lost to and political disarray effected by the disease, it's reasonable to believe that the rat—and its attendant plague—precipitated the beginning of the end of the Byzantine Empire.

Over one millennium later, the third and final plague pandemic jolted East Asia, starting its trajectory in China in 1855 (Ziegler, 1997). It is in the context of this third pandemic that Yersin and Kitasato resolved to discover the plague pathogen. By 1898, the pandemic's perimeter reached as far as Bombay, India. As a whole, the rats and their fleas killed millions of people in the affected regions. According to Byrne (2012), infected rats touched down in Hawaii by 1899, hitching a ride as stowaways on a ship. The rats that presaged mass suffering were one step closer to reaching the mainland United States. Fatefully, a Japanese ship carrying both rat and human cases of plague arrived in California in 1900, the Chinese Year of the Rat (Hendrickson, 1999).

Wedged in between these two pandemics, though, is the Black Death, perhaps the most lethal scourge in history. Whisperings of a fatal disease in the east slowly trickled into Europe in the mid-fourteenth century (Ziegler, 1997). Despite the alarming casualties suffered in China at this time, Europeans did not have much to anguish over. It was uncommon for happenings a thousand miles away to have any bearing on medieval Europeans. But it was not long before the

pandemic expanded its wrath toward Europe. As before, this instance of the bubonic plague probably traversed the vast expanse separating China from Europe by the popular trade routes and military ventures of the time. The clash of Turkish and Genoese soldiers in 1347 coincides with the emergence of bubonic plague in Europe (Ziegler, 1997): As a Turkish fleet surrounded the Genoese port city of Kaffa, the Turks realized they would not triumph. To at least make an impact, the Turks—themselves harried by plague—flung their dead by catapult into the town of Kaffa, reminiscent of a tactic of the Mongol Empire. The Genoese fled the port. But they were not alone. With them came rats. And with the rats came *Y. pestis.*

Once on mainland Europe, by way of Italy, the Black Death ravaged unobstructed. This second pandemic persisted in uprooting European society until the eighteenth century (Hendrickson 1999). People in afflicted towns had to fundamentally change their ways. How people related to one another mutated, with mistrust and finger-pointing abundant. The economic output of Europe fell precipitously; farmers did not live long enough to reap what they sowed. Along with plague, Europeans were infected with uncertainty. If people could not reasonably assume anymore that they would still be alive in a week, then life seemed devoid of meaning itself. This existential concern, coupled with famine precipitated by shorter summers, colder temperatures, and wetter weather, disrupted any semblance of order (Byrne, 2012). As European society devolved into disarray, nobody suspected that the lowly rat lay at the bottom of all this seismic change.

The Black Death's impact

The specter of the Black Death spawned much activity and restlessness in Europe. For one, the Black Death gave rise to many writings documenting the course of the pandemic. Perhaps the most celebrated of these writings is *The Decameron* by Giovanni Boccaccio. Even though *The Decameron* is largely a work of fiction, its accurate depictions of the sheer desolation of France and the moral dissolution of its inhabitants injects the collection with realism; this proves helpful in understanding the plight of the people enduring the plague. Contemporary accounts such as Boccaccio's illuminate the harrowing reality of the Black Death for people many centuries removed from the horrors. One disconcerting quality of the plague—for those who lived it—was its mysterious character; people did not know its precise origin, its route of transmission, or its cure (if any). Arguably worst of all, nobody knew if it would ever go away.

In spite of all the confusion, Europeans did their best to keep plague's spread at bay. One of these methods devised under duress is still critical for the containment of disease today: the quarantine. First developed in what is present-day Croatia, the quarantine was an official decree that all ships from infected areas had to abide (Byrne, 2012). The quarantine was this area's solution to the predicament of how to repel plague without sacrificing commerce. The first quarantine law required the ships to maintain a certain distance from the port for forty days—*quaranta giorni*—before docking. The legacy of this disease management system endures. The bacillus *Y. pestis* was not identified until the third pandemic in China and India, but that did not preclude the medieval Europeans from having their own speculations on the origin of the plague. It's telling that rats didn't figure into their hypotheses. To us, the writing was on the wall. Predating the scientific revolution, however, those suffering from plague in the fourteenth century devised some curious explanations.

The historical period during which plague struck humanity hardest was the Middle Ages. Some notably refer to this era as the Dark Ages to elicit the notion of this time's perceived backwardness or lack of progress; in reality, this term denotes the period's comparatively low volume of historical records. Nevertheless, the scientific method had not yet permeated Western civilization at this point in history, so theorizing about the origins of plague was inevitably to be fraught with error.

Germ theory (not proposed and accepted until the nineteenth century) could not inform the extant thinkers during the plague. Instead, those in the fourteenth century attempting to speculate on the etiology of plague worked through the lens of a different yet erroneous one: miasma theory (Rosen, 1993). Miasma theory anchored disease, in general, in the concepts of purity and contamination. From place to place, the air carried particles. Under certain circumstances, these particles could be tainted. One common source of impure air—of miasma—was the emissions of dead and decaying organisms. In addition to the conviction that poisonous air was the seat of disease, the religiosity of the time—Judaism and Christianity alike—provided yet another set of goggles through which to make attributions. Many observers of the plague interpreted the pestilence as divine punishment for widespread iniquity (Kelly, 2005). Therefore, it was the responsibility of God to inflict punishment on the sinful society, here in the form of plague. The miasma theory mentality, coupled with a religious ethos, rationalizes an array of seemingly strange medieval practices to avoid and cure plague. Some people doused themselves in strong odors (Hendrickson, 1999). These odors included human excrement, urine, the first colognes, and menstrual blood, predicated on the belief that eclipsing the miasma with a stronger scent would expel the noxious air from the area. In light of the divine origins of plague, all one could do was pray.

The frenzied search for the cause of plague compelled the insidious blaming of others for one's problems, too. Anybody deemed exotic could fall victim to this blame game, but the group most commonly judged responsible was the Jews (Sullivan, 2005). The Jewish people act as scapegoats many times throughout history; this time is particularly egregious. Christians disseminated rumors depicting Jews poisoning town wells with plague. Outraged, pogroms against Jews commenced in diverse regions of Europe. Byrne (2012) states that most modern historians accept that Jews perished from plague proportionately to Christians, so it is ironic that the bulk of the blame was centered on the Jews; but this illustrates the hysteria characterizing the event. In the end, though they didn't in fact propagate the disease, Jews—especially in the diction of Adolf Hitler—would ultimately be classified under the same category as rats: vermin.

The brunt of the Black Death occurred in the middle of the fourteenth century. Smaller pockets of infection cropped up around Europe until the seventeenth century, when the last bout of plague attacked London (Byrne, 2012). As mentioned, the rats escaped suspicion for hundreds of years. Even if some observers noted the presence of dead rats near sites of plague devastation, it was not until the advent of germ theory that scientists could explain this correlation.

Plague in the US

The rat's central role in plague's devastation colored people's attitudes toward the animal. If not already tarnished, people's attitudes towards rats were hostile, even vengeful for the perceived injustice of the rat's role in the spread of plague. Americans, too, would have their own bout with plague to shape their feelings toward rats. This resurgence of plague in America, a

manifestation of the geographically wider third plague pandemic, prompted political panic and deception.

San Francisco, California is the epicenter of America's experience with plague (Byrne, 2012). *Y. pestis* first traversed the Atlantic via ship rats in 1899, landing first in Honolulu (with a small outbreak there), and completing its journey to the mainland US. Once in California, plague could—silently at first—begin its American tour. Paralleling the racism toward Jews in the causation of plague—and history at large—racism toward the Chinese allowed the plague to infiltrate the US without detection in the beginning. The first US fatality due to plague, Chick Gin, was of a Chinese man in the area's Chinatown (Kalisch, 1972). A medical examiner on the case grew inquisitive of what he saw on the man's body: swollen lymph nodes in the groin—the telltale sign of bubonic plague. The medical examiner, not wanting to incite panic, contacted some colleagues to conduct further tests to divulge the true cause of death. Once the team's bacteriologist confirmed that the man's swellings were brimming with *Y. pestis*, it was clear that the US had encountered their first plague outbreak (Sullivan, 2005).

The city reacted unexpectedly to the news of plague in their midst. Kalisch (1972) amalgamated numerous reports from the press of the time. Many outlets disparaged any claim that San Francisco legitimately was threatened by a plague outbreak. Most papers believed (or at least published) that the San Francisco board of health was inventing an epidemic scare so as to bolster their reputation and to garner financial funding. Obviously, the rats were escaping attention yet again. Something mischievous was happening. Plague, notably, suppresses the economic activity of its host city. Apparently, both San Francisco political and business leaders judged the continuation of "business as usual" in their port city as paramount—more important than containing or even admitting the presence of plague. Furthermore, racial tensions tightened

as the immigrant bacteria and the immigrant Chinese were inextricably linked together. The city wanted to simply rope off Chinatown so they could turn a blind eye to the amassing plague threat; the Chinese population of Chinatown resisted investigations of those dying in their community to avert any discrimination (Kazanjian, 2012). Ignoring the insistence of community scientists, the city stood idle as the death toll from plague climbed to thirteen.

Eventually, the arrival of a commission of outside, disinterested scientists accelerated the closing of this plague chapter (Kazanjian, 2012). These investigators streamlined the process by hiring a Chinese interpreter—someone who could bridge the language barrier and ensure the observance of the strict Chinese cultural phenomena relating to the dead and dying. Once granted permission, the researchers confirmed case after case of bubonic plague (Kalisch, 1972). The involvement of the US attorney general, coupled with other states' concern for their own safety, culminated in a collective threat to embargo all traffic to and from California (Kalisch, 1972). Threatening California's economic prosperity proved effective in grabbing their attention. Thereafter, the prominent business organizations, in a complete about-face, zealously admitted to the existence of plague in their backyard and lobbied for curative measures to be implemented (Kalisch, 1972). Following a year of cleaning up—including the untimely deaths of scores of rats—San Francisco rid themselves of plague.

Owing to the glacial pace of scientific thought, conflicts of interest, mass hysteria, and the futile persecution of convenient scapegoats—Jews and Chinese, for instance—the rats were left alone to propagate plague at several grim moments in history. Plague's devastation has visited diverse regions of earth: the Americas, China, India, and Europe. Of course, the brunt of plague's impact fell on Europe of the Middle Ages, but the memory of plague's indiscriminate killings is everlasting. The association between rat and disease, namely plague, is inseparable.

People's attitudes are sculpted out of a complex series of inputs; attitudes towards rats are no different. I wager that a large portion of the natural human aversion to rats is a result of rats' participation in the diffusion of plague, principally in the Black Death. Granted, the victims of the Black Death never connected their suffering to the activity of rats. Yet today, we know of the part played by rodents and are a long way from forgiving them.

A gluttonous appetite

The rat's hand in spreading disease provokes much wrath and contempt. If their mere existence is bad for our own, then the hatred of rats seems well-justified. This outrage has another dimension, though: their appetite. The rat's appetite astonishes us, only matched in scale by that of human beings. Albeit dentally designed for the consumption of hard grains, rats are a marked departure from picky eaters (Barnett, 1975). They eat virtually everything. Though we deplore the comparison, voraciousness is a common thread uniting rats and us. It is their insatiable appetite, though, that pits them against us. Since we are after the same limited resources, conflict is inevitable. Rat-human strife, as related to their harrowing appetite, comes in several forms. For instance, their effect on our agricultural productivity is nearly incalculable. In urban environments, too, rats live so closely with humans because they delight in the heaps of garbage we leave on the streets, graciously waiting to be eaten by a hungry rodent. Finally, rats interfere with the human desire for biological diversity in the world; when rats enter a new ecosystem, they tend to completely destabilize the equilibrium established there by the native species, resulting in many near extinctions, predominantly among seabirds on islands—the rats feast on their eggs and even the birds themselves. Yong (2018) describes one such unfortunate chain of events surrounding an island in the Indian Ocean. The island's birds usually cycle

precious nutrients from farther waters back to the island in the form of their excrement, furnishing the island with highly coveted nitrogen to boost soil productivity. This nitrogen reaches the coastal waters, promoting marine life, too, including the threatened coral reefs. When the island's rats—introduced by humankind—markedly reduce the seabird population, organisms at the far end of the chain, the coral for instance, suffer as well, exemplifying the interconnectedness of life on our planet. This pattern plays out on many islands. Attracting human attention, the island ecosystem's tenuousness has motivated teams of conservationists to de-rat the islands. Some have declared victory already, such as in South Georgia Island, and others expect more success in New Zealand by 2050 (Yong, 2018). As humans devise means to reach greater evolutionary success, such as the development of agriculture in the first place, rats co-evolve with us, crafting strategies and acquiring traits to become equally, if not more, successful than we are.

One archetype of this interminable between-species conflict brings us to Mizoram, a state in northeastern India. The flowering of a bamboo plant is exceedingly rare; these plants bear fruit so rarely that a person is only likely to witness the phenomenon once per lifetime (King, 2009). The locals, however, do not celebrate the flowering. This event portends suffering on a large scale. With the newly displayed fruit comes an astronomical explosion in the rat population. The bamboo fruit never provides enough of a bounty to feed the newly magnified rat population; the rats must find an alternative source. At this point, the interests of the rat and those of the local farmer are irreconcilable. Akin to one of the Egyptian plagues, hordes of rats race through the rice paddies, consuming everything in their path and leaving nothing in their wake (King, 2009). The rats' appetites are so insatiable that they leave nothing but desolation for the human farmers, making it necessary for the government to provide supplemental food rations for the farmers

(Bhaumik, 2007). King (2009) also states that, during one of these episodes (referred to as Mautam), the rats reduced the expected rice yield from 4,000 pounds to a mere 50 pounds. This means the rats eradicated over 97% of the harvest. Truly, the interests of rat and man can be heavily incongruous.

The devastation unleashed by rats on crop output is particularly heinous; it is also timeless. Even Aristotle warned that merely a small quantity of rodents can destroy an entire field in a single night (Jacob & Tkadlec, 2010). Rice, a staple of certain Asian countries, is notably susceptible to the hunger of the rat. According to Sudarmaji (2010), Asian rice farmers can lose roughly 10% of their crop—with some variation—due to rodent pests alone. An estimate by Capizzi, Bertolino, and Mortelliti (2014), sets the annual crop production lost to rats at approximately thirty million metric tons. With abundant hunger in the world, it behooves us to keep rat numbers in check.

Problems like these—in addition to the risk of disease and our general distaste for rats—have motivated people to work toward minimizing rat populations for much of history. It's unclear, in the unremitting battle between rats and humans, who is winning. Although pest control agents have devised an arsenal of methods to vanquish the rat, rats are still here. Their ubiquity is a testament to how successful they are as a species, despite our best efforts to quell their numbers. The past and present of this rat war provides some interesting tales on the history of our interactions with the world's second (or maybe first) most successful creature.

Early efforts at control

The most famous exemplar of a rodent control specialist is the titular character of the *Pied Piper of Hamelin*, a medieval legend set in Germany. Authors the world over have told many variants of the story, but at its core, the legend recounts a story of a rat-catcher, and a real one at that. The pied piper, so called for his two-colored garment and alluring musical pipe, is fabled to have visited the town of Hamelin in the thirteenth century (Hoffman, 2011).

Allegedly suffering a massive rat infestation, the town of Hamelin commissioned the pied piper to rid the place of rats. Upon agreeing on a certain sum of money, the pied piper lured the rats into a nearby river, the rats apparently unable to resist the melodies of the piper's pipe (Hendrickson, 1999). (Unaccountably, this story neglects the fact that rats swim with ease.) The task complete, the pied piper returned to Hamelin to accept his compensation, yet the town refused to pay (Hendrickson, 1999). The pied piper, furiously aggrieved, left the town only to come back later to exact revenge. He, with the same pipe as before, musically compelled all the community's 130 children to follow him out of town. Where the pied piper directed these children depends on the source. Here is one of the earliest accounts of rodent-control. Strikingly, the story casts the rat-catcher in a negative light; generally, people root against the rats.

Humans aside, early attempts were typically a multi-species affair. Humans, not wanting to get their hands dirty, recruited other animals to get the job done. The variety of dogs, their capacity to be ruthless, and their kinship with humans all rendered them a powerful weapon to be deployed against rats. Still, a constant in the fight against rats, these attempts are replete with failure. As an illustration, one of the biggest blunders is set in the time of the Black Death. Although people were growing cognizant of the presence of dead rats in areas struck by plague, the causal relationship was never established. Instead, people mistakenly placed the blame with

dogs and subsequently began a mass extermination of them (Hendrickson, 1999). There's a high probability that these human efforts indirectly resulted in a higher incidence of plague; with dogs out of the picture, rats were left unperturbed to transmit plague from town to town.

Rat fights

In time, though, the world recognized rats as a cause of dissolution and began recruiting dogs for the job of eradication. Humans successfully and artificially selected certain breeds of dogs into existence for the purpose of hunting rats. So much so, in fact, that this dynamic transformed from one of necessity into one of diversion: the spectator sport of ratting (Sullivan, 2005). As the dogs grew exceptionally adapted to this task, it mutated into a blood sport. People entered their dogs in competitions to face off against other dogs. The dogs didn't fight each other, though. Rather, the winner was the dog who could kill a specified number of rats in the lowest amount of time (Mayhew, 1851).

In the mid-nineteenth century, journalist and social reformer Henry Mayhew undertook to describe the impoverished class of London (Sullivan, 2005). Mayhew left many volumes of books describing the activities of this class. His writings intersect with the present discourse in its treatment of how the London poor interacted with the city rat, the preferred mode being that of ratting introduced above. Mayhew (1851), in his journalism, finds that the London workers believed that the only way to counter the rat's exponential fecundity was to artificially control their numbers:

> the principle of increase is much more powerful, active, and effective in the common grey rat than in any other animal of equal size…[if] the rat produces ten litters in the

> course of a year, and that no check on their increase should operate destructively for the space of four years, a number not far short of 3,000,000 might be produced from a single pair in that time!...If, therefore, rats were suffered to multiply without the restraint of the most powerful and positive natural checks, not only would fertile plains and rich cities be undermined and destroyed, but the whole surface of the earth in a very few years would be rendered a barren and hideous waste, covered with myriads of famished grey rats, against which man himself would contend in vain.

To the London working class, this called for extensive population control measures. Why not make a sport of it?

According to Mayhew (1851), the sport of ratting engendered a sort of microeconomy among the London poor; Londoners engaged in the trapping and subsequent buying and selling of city rats. This removed considerable rat numbers from the streets of London while, in addition, supplying the local rat pits—the setting of the dog competition mentioned earlier—with fodder for sport. The sport proved immensely popular. The New York City working classes also embraced the sport with open arms (Sullivan, 2005). Rat pit entrepreneurs provided ample space for spectators, leaving room for several hundred onlookers. The pits could expect this kind of attendance at each showcase. Describing one notorious pit, Sullivan (2005) says the following:

> It was a wooden-walled oval on the dirt floor, seventeen feet long, eight and a half feet wide, with benches and boxes for the patrons. The rats entered in a wire cage the size of a large pail; they came in fifty at a time, rats screaming and hissing. When the dogs saw the rats released, they howled, setting the rats into a frenzy. (p. 77)

The sport was not without opposition. New York's Society for the Prevention of Cruelty to Animals resolved to end the practice (Sullivan, 2005). With the help of the police and with much strain, all of the ratting pits were eventually shut down. Some of the perpetrators were baffled that what they were putting on could be considered illegal. William F. Howe, a renowned defense attorney of the late nineteenth century, "argued…that the men did not set the dogs against each other…that the men were only rat fighting" (Sullivan, 2005, p. 81). How could this be illegal? Today, we might find blood sports such as ratting unconscionable, but the sentiment was not so pervasive toward the close of the nineteenth century.

Other animal foes

A menagerie of animals have participated in humanity's efforts to distance themselves from rats. Some naturally hunt for rats; others need some prodding from humans. One of these that we typically consider successful—though this may be untrue—is the cat (Hendrickson, 1999). Cats insinuated themselves into human societies roughly six millennia ago (O'Brien, 2004). Just like dogs, both the humans and this companion animal benefited from the bargain; humans had some assistance in hunting and warding off pestilent animals like rats, while the newly domesticated animal had easier access to food. We discovered the hunting acumen of cats—or they discovered the abundance of humanity—much later in history as compared to the dogs (O'Brien, 2004). We intuitively identify the cat with supreme Egyptian reverence. It is most likely that this Egyptian feline esteem derived from the cat's rodenticidal behavior (Hendrickson, 1999). As the cat, however, began to be valued by humans in their own right as a companion animal, their rat-killing tendencies deteriorated; after all, if humans reliably provided ample food for cats, it would be unnecessary for cats to continue expending energy on hunting. Again,

analogous to the dog's fate, medieval plague hysteria led humans to target cats, along with dogs, for destruction, so rats had another predator it didn't have to think about (Hendrickson, 1999).

Ferrets and mongooses, too, posed a threat to wild rats (Hendrickson, 1999). Ferrets can easily negotiate the narrow passages of rat holes underground, rendering them apt for predation. Counterintuitively, in light of the ostensive success of ferrets and rat-hunting, not many urban areas employ ferrets for this purpose. The mongoose, though, has a richer history. The mongoose has been released into the environment several times to counter the pernicious activity of introduced rats on local fauna (Barun, Simberloff, Tvrtkovic, & Pascal 2011). Rats affect the local populations by either directly preying on local animals (bird eggs and bird adults) or by indirectly killing the local animal through competition for scarce resources (seeds and other plant material); they occur in this guise on 90% of the world's islands (Jones et al., 2008).

Human civilization has accordingly adopted measures to moderate—or annihilate—the invasive rat colonizers. Of course, it was only through human vessels that rats were able to migrate to these new island locales, hitching rides as stowaways on seafaring ships. Barun et al. (2011) explains that a collection of ecological control efforts entailed the use of the mongoose in the late nineteenth century. The aim was to eliminate the invading rats, who were decimating the local farmer's crop yields. The expectations, in fact, differed from reality. Granted, the introduction of the mongoose was attended by a decline in rodent populations. The new mongoose population, though, engendered two unforeseen consequences: First, the mongoose itself proved to be a rather destructive creature. In a sense, the rodents lost to the new mongoose community were simply replaced by the mongoose; the mongoose appetite displays no modesty, and the mongoose preyed upon many of the same plants and animals that the rat did. Second, rats, as observed through all history, are more conniving than they appear at a glance. Like

humans, rats are adapted for change. Perhaps their dynamism is indeed their most adaptive characteristic. Partly owing to their high fecundity, the lowly rat can adapt to environmental change swiftly and in only a few generations.

In response to the introduced mongoose, rats changed their waking hours to contrast those of the mongoose (Barun et al., 2011). Generally nocturnal, rats hunt and forage for food at night. The mongoose, too, is more active at night; this necessitated a change from the rats, which they were ready and willing to do. In effect, the rats in areas with introduced mongoose populations shifted from nocturnal to diurnal. The same logic applies to pet rats; anybody who has had a pet rat might recall that their pet, upon learning the typical behavior of their owner (including feeding times), will augment their own sleep schedule to match that of their owner. The rat's abilities to predict when they will be fed based on past experiences and overcome instinctive behavior to exploit an opportunity are but a couple of pieces of evidence highlighting rat intelligence.

Despite this squadron of animals thrown at them, rats nonetheless manage to evade depredation. Much to the predators' chagrin, rats have evolved a set of defenses to avert death. For instance, there's an abundance of research on the chemosensory apparatus of rats; it seems that predator-specific odors from urine, fur, and other glands signal the predator's approach or presence to the rats (Dielenberg & McGregor, 2001). Instinctively, rats exhibit avoidance and escape behavior in response to predator scents, even ones never encountered before (Berdoy, 2002). Again, it's clear that rats are evolutionarily primed for survival; they have innate predispositions to avoid their natural predators.

Jack Black: royal rat-catcher

Probably the most sagacious animal in rodent control is *Homo sapiens.* In possession of higher mental faculties and technological knowledge, we have an edge in the fight against rats. A contemporary rival in rat death toll to the dogs of the pits was Jack Black, a London rat-catcher emitting charisma and showmanship uncharacteristic of the pest control industry (Mayhew, 1851). He'll emerge again later in the origin story of lab rats and fancy rats (pet rats), but for now, Jack Black factors into this story as the preeminent rat-catcher of Victorian London. Black's position at the juncture of all three body chapters of this thesis illustrate just how crucial he is in the story of rats.

Jack Black's relationship was rats can only be described as unprecedented. Supposedly, he handled the rats in public exhibitions "as if they were so many blind kittens" (Mayhew, 1851). Both Black's curious comfort with handling rats and his traveling exhibitions are unique to him. Black, in his self-designed uniform, paraded from town to town to display both his preternatural ability to handle rats and his special concoction to kill them (Edelman, 2002). Evidently, Jack Black knew how to effectively market his talent to the people of London. Edelman (2002) also writes that Black was an ample supplier of the rat pits discussed above. The public exhibitions Black performed generally engrossed large crowds of people. A veritable showman, Black engaged the swaths of people with such acts as dipping his arm into a large cage of live rats and allowing the creatures to scamper about his body (Mayhew, 1851). Remarkably, the rats never bit him during the public displays. This contradicted the common conception of rats as inherently nefarious animals. Still, Jack Black is likely history's top rat-catcher.

How to trap a rat

The common conception of how to capture a rat is one of deception. Whether the objective is to kill the rat or keep it alive, the protocol tends to involve luring the rat to the trap with food, while maintaining the aura of a safe environment so as not to spook it. Evidently, the rat's gluttonous appetite is known widely; we exploit this property in order to control rat populations. The almost comical snap trap—the wooden plank, the spring-loaded wire mechanism, and the tantalizing piece of cheese as bait—is not particularly successful at tricking rats; they're smarter than that. Thus, pest control agents and rats are engaged in a back-and-forth battle of wits, the pest control agent trying to exterminate and the rat trying to survive. The rats, with their lives on the line, seem more than capable of defending themselves. An array of instincts renders them sufficiently suspicious and perceptive of their surroundings, making the exterminator's task an unending puzzle.

The surfeit of garbage we leave in the street attracts the rats to our vicinity. Rather than the seemingly simpler method of cleaning up after ourselves, pest control agents use the food to their advantage: They poison it. The discovery of warfarin was one of the greater breakthroughs in the history of rodent control (Sullivan, 2005). Warfarin is an anticoagulant, meaning it obstructs the capacity of blood to clot; in the case of injury, without a functioning clotting mechanism, the injured animal in question will bleed to death. Chemical agents directed against rats would prove doubly effective considering rats lack the requisite physiological mechanism to vomit (Barnett, 1975). When entire herds of cows started dying in both Canada and the United States in the 1930s, researches inquired after the cause (Rajagopalan, 2018). The deaths bewildered the farmers as usual events such as dehorning resulted in the cows bleeding out until death. Eventually, veterinarian Frank Schofield observed a correlation between the bleeding out

events and particularly rainy summers (Rajagopalan, 2018). He surmised that the chemical reaction of molds with the sweet clover fed to the cows yielded a strong anticoagulant. After some heavy analytical chemistry, Harold Campbell discovered the bloodletting agent: 4-hydroxycoumarin, also known as warfarin. Rat-control personnel quickly jumped on the opportunity.

Rats, however, have a protective response to attempted poisonings: They are highly wary of new things in their surroundings. This neophobia is well-documented in the rat literature, perhaps so frequently mentioned that it may be one of the defining characteristics of the rat. Anecdotal reports of fruitless attempted rat poisonings abound; they usually entail aggrieved farmers leaving out poisoned food and the rats leaving it untouched. Explaining this reaction to the food is the concept of *neophobia*. Researchers initially termed this response the New Object Reaction, but S. A. Barnett (2001), a large figure in rat research, rechristened it neophobia, the fear of novelty. Even starving rats will avoid new food placed in the environment for a couple of days to ensure it's safe to eat.

This anxiety over the safety of food constitutes a larger predicament affecting a specific class of animal: omnivores. Most famously expounded in Michael Pollan's (2006) *The Omnivore's Dilemma*, this paradox of the same name proceeds accordingly: Omnivores, like rats and humans, have a broad selection of food to choose from, covering the gamut of plants, fungi, and animals. But this large menu presents the consumer with a problem, as many of these plants, fungi, and animals have evolved defense mechanisms to avoid being eaten by us omnivores. Some of these defenses, usually in the form of toxins, can kill. According to Pollan, "[T]he blessing of the omnivore is that he can eat a great many different things in nature. The curse of

the omnivore is that when it comes to figuring out which of those things are safe to eat, he's pretty much on his own." (Pollan, 2006, p. 287)

The omnivore's dilemma prompts suspicion in any omnivore looking for a meal.

Humans have resolved this paradox; our culture passes down through posterity acquired knowledge about what is and is not safe to eat. Rather than a gene controlling our actions, it is a transgenerational idea. Rats had to devise a different strategy, one accounted for by Paul Rozin, a psychologist curious about food selection in omnivores like rats and people. Rozin (1976) found that rats, to overcome this problem of selection, may sample a miniscule portion of a given food and wait for any adverse reactions in the future. If the rat does not fall ill, it can remember that this is and will be a safe food source for the future. In fact, this notion in and of itself is remarkable: that the rat can connect cause and effect over large spans of time. Moreover, rats deprived of certain nutrients, such as calcium, and presented with a variety of different foods will adjust their diet accordingly in a laboratory setting to replenish the missing nutrient (Rozin, 1976).

Both the strategies employed by humans and rats suggest that omnivores need to be in possession of greater cognitive capacities than their specialist counterparts who only need one or a few food sources to survive. Perceptiveness, learning, and memory all characterize omnivores in their relationship with eating. Although the food life of an omnivore is clearly complicated, their expansive eating style enables these creatures to dominate any ecosystem around the world. Again, citing Pollan (2006),

> eating might be simpler as a thimble-brained monophage, but it's also a lot more precarious, which partly explains why there are so many more rats and humans in the

> world than koalas. Should a disease or drought strike the eucalyptus tree in your neck of the woods, that's it for you. But the rat and the human can live just about anywhere on earth, and when their familiar foods are in short supply, there's always another they can try. (p. 290)

It's apparent that rats and humans are apt to fill many ecological niches. Their reach and numbers certainly reflect this.

Alone, avoidance behavior will not endow an animal with what it takes to survive. An animal must also possess an innate mechanism priming them for exploration. This exploratory behavior (neophilia), indeed, is seen in rats. In one of Barnett's (2001) experiments, rats placed in new cage environments with three distinct corridors promptly explored all three wings of the cage; several days after, when the rats gained access to a final corridor, they still unhesitatingly explored the new section and continued to patrol the other sections in their daily activities. Furthermore, Barnett (2001) has observed that food-deprived rats placed in a new cage environment will, astoundingly, continue exploring its new surroundings even after finding the area with food. How can we reconcile the apparent discordance between rat neophobia and neophilia?

Rats may avidly explore new environments, but should a new object—like food—appear in a familiar environment, the rats will vigorously avoid this area, sometimes for many days (Cowan, 1976). Rat neophobia, therefore, adopts a specific form: Rats will avoid a new object in a familiar area. Anything else is fair game. Impossible to certify, it seems plausible that rats developed this wariness for certain sorts of novelty by growing up around a hostile neighbor: human beings. As humans continually try to kill rats, rats with higher levels of skepticism are

better suited to survive. Thousands of years of this resulted in a species highly distrustful of humans.

In the realm of pest control, other technologies have been developed to fend off rats; these include an ultrasonic noise emitting device—since rats hear in this range—and a scent emitting device of rat predators. The technologies, for reasons unknown, proved fruitless. Rats are harder to fool than we think; there is a whole corpus of research devoted to addressing the question of rat intelligence, most of which lands on the affirmative and will be examined to some extent in the next chapter. For now, though, myriad rat behaviors inform us of how rats function as successful pests. Attributes such as their small size, prolific reproductive rate, and wariness around humans have provided rats a clear avenue for evolutionary success. For instance, even if rodent-control personnel were to effectively decimate a given rat population, this would merely allow for a huge population explosion as the resource to rat ratio skyrockets, soon replenishing their numbers. Unfortunately, their goals and ours don't always intersect, and often they clash.

Conclusion

One subtle mechanism exterminators deploy against rats is the bait station. This black, compact box encloses poisoned treats off from the environment to ensure that only the intended targets, rats, consume the bait. The box has entrance holes only wide enough for rats to fit inside, keeping larger animals, like human children, out of the mix. The rats, who favor small spaces, willingly enter the bait station; whether they eat the bait is another question.

In my first semester at the University of Texas at Austin, I enrolled in a class entitled American Animals: A Cultural History taught by Dr. Janet M. Davis. The aim of the course was

to investigate how human-animal interactions have shaped the wider American culture. One unit of the course concerned urban wildlife pests. Specifically, this meant we would be studying rats. During this section of the course, Dr. Davis invited her students to walk around UT's campus with her (Davis, 2015). She wanted to convey the ubiquity of these rat bait stations. From that moment on, I've spotted these subtle devices in virtually every US city to which I've traveled. To me, this box represents humanity's expansive, but fallible, effort to rid itself of these resilient animals. But, to the dismay of many, rats nonetheless flourish. In the face of the constant assaults we levy against them, rats persevere, perhaps another way they are like us. We built cities in part to distance ourselves from the harsh realities of nature, but in constructing a haven for ourselves, we inadvertently created one for the rat as well.

Chapter 2: The Key to Discovery

Nothing epitomizes the popular spirit of laboratory research on rats better than the maze. To the layman, at least, the mention of rat testing immediately conjures images of a maze. As portrayed in an immeasurably large number of movies and television shows, the researcher places the rat at the beginning of the maze; at another point, the researcher places an alluring treat that the rat is motivated to find. With many false corridors in the maze, the rat will reach some dead ends but eventually finds the endpoint, the treat. After basking in the reward, the rat is set at the beginning of the maze once again. In general, the rat solves the maze faster this time. The rat's increasingly fast maze runs suggests that they are learning the geometry of the maze. Thus, experiments like these support one manifestation of animal—or at least rat—intelligence.

Nevertheless, this popularly conceived, classic maze is but one type of maze aimed at studying only one thread of possible rat research. Other tools of the trade comprise Y-mazes, T-mazes, and radial arm mazes, all aimed at various components of rat behavior (Hanson, 2012). Additionally, of more readily apparent interest to us, the field of biomedical research is one in contrast to the more general pursuits of the basic research cited in the classic maze discussed first. Biomedical researchers concern themselves with uncovering immense anthropocentric discoveries, the breakthroughs that make the news. They aim to advance human health and well-being, not merely to discover for discovery's sake. Of course, scientists can't proceed to test all their hunches on human beings—some experiments inflict pain and discomfort on the subjects; they need a substitute, a model. I purport in this chapter to explain the utility of animal models in the lab, namely the use of rats. I begin with discussing models in general before narrowing the focus to only lab rats. I then analyze what makes rats the ideal animal model for human biology and behavior. Finally, I close with some common methods to gain insights from laboratory rats.

Surely, some laboratory animals are studied simply for their own sake, in order to gain insight into that particular creature; this is the province of comparative psychologists, ethologists, and others. Probably, though, the animal is only a surrogate for human knowledge. Researchers test their hypotheses on non-human animals since some of this testing entails experimental methods which can cause considerable distress to the participant, both physical and psychological. Due to some morally intractable beliefs which would take tomes to demystify, we, as a society, are generally receptive to experimenting on animals in our stead. Somewhere in the dialectic of defending animal testing, we decided that human life exceeded non-human life in value, embodied in the doctrine of humanism. The veracity of this claim has made careers in philosophy; it will not be discussed at length here. This thesis accepts the animal's status as research model and discusses the implications of it.

What are models?

"The top animal models offer our best hope for discovering information that will lead to cures for the various diseases that haunt us" (Lambert, 2011, p. 9). Kelly Lambert, a behavioral neuroscientist at Randolph-Macon College, knows a lot about rats; she's made a career out of them. She appreciates the tremendous scientific progress we've made through laboratory work, much of it owing to research performed on rats. Aside from this pure discovery gained as such, Dr. Lambert has examined the methodology of using lab rats and written much on this point. Before, however, we delve into the place of rats in science, we must zoom out and talk about animals in the lab as models. Models allow scientists to investigate phenomena that would be impossible or immoral otherwise. Instead of subjecting humans to potentially painful (or fatal) testing conditions, researchers can apply these conditions to an animal representative instead.

Ideally, there is enough similarity between the animal surrogate and the human to transfer the results of the animal subject to human applications.

Animal models function on the basis of analogy (Shapiro, 1998). Scientists draw some sort of analogy between humans and the animal which will represent them. This implies a similarity between the two, but not an identity. Minding how the two animals differ, scientists can draw inferences about an animal they know little about (humans) from research on animals they know much about (rats). According to Shapiro (1998), for a model to contribute substantially to science, one assumption must be made: Two things with some attribute in common most likely have other attributes in common. Suppose a new animal species were observed to ostensibly share a host of characteristics in common with humans; one could deduce that it shared with us at least some internal processes. It is on this foundation that the entirety of animal testing rests. If crumbled, animal experimentation has nothing to support it. Obviously, ethical objections to animal testing abound, relating to notions of animal cognition, emotion, and desires, but scientifically, the real determiner for using animal models is whether we can extrapolate findings from animals to humans.

Dismissing ethics for now, the object of developing animal models is to furnish scientists in the lab with more precision in the manipulation and control of variables. We can't expose human participants to temperature extremes, experimental drugs, or other adverse or abnormal conditions in the same way we can to animals. By the same token, scientists can more flexibly keep variables not of interest constant when operating on animals; in controlling for a slew of variables which could not reasonably be held constant in humans (diet, light-dark cycle, temperature, stress), researchers can more confidently affirm that it is the variable of interest—and not some other confounding variable—which is yielding a given outcome (Meyer &

Quenzer, 2013). Though the ethical waters are murky in how we treat animals, we universally agree that it's unethical to treat humans in these ways.

Though it may appear inappropriate to ground human knowledge in non-human animal physiology and behavior, models are nevertheless useful to us. According to the National Research Council (2004), "humans have 65 infectious diseases in common with dogs, 50 with cattle, 46 with sheep and goats, 42 with pigs, 35 with horses, and 26 with fowl." These numbers reflect how much we have in common with other species despite the common knowledge. As part of Jared Diamond's thesis in *Guns, Germs, and Steel* (1999), many human diseases actually derive from some non-human animal variant. The increasingly close proximity of our ancestors over time to these animals enabled the interspecies spread of disease. In time, the originally animal-bound pathogens developed adaptations facilitating their infiltration of the human species. In sum, it makes perfect sense that we share several identical—and even more similar—diseases with our animal brethren.

Meet the animals

Scientists exploit an extensive range of animal species to generate and subsequently test theories. Size, cost, and physiology of the particular animal all converge in the scientist's decision of which to use in their specific protocol. For example, depression, Alzheimer's, and cancer are characterized by vastly different features and therefore require different animal models. Overall, animal-based research is a multifarious affair. Animal models form the basis of research in several domains. Most familiar to the average person is its position in education. Higher institutes of learning are the most ravenous of laboratory animal users. Scores of research

papers founded on animal testing are published daily, whether this be in the realm of psychology, biology, chemistry, or engineering. Moreover, the research can be basic (to further general knowledge) or applied (with a specific end motivating it).

It's intuitive to consider the benefits of using animals in medical and especially veterinary education, but the majority of people—regardless of their higher education attainment—have experimented with animals in one sense: high school animal dissections. Whether the hapless creature was a frog, fetal pig, sheep eye, or the notorious rat, most of us have in actuality partaken in animal research. High school dissections probably don't constitute a great portion of the animal research undertaken in the US, but this domain, likely, most intimately influences the public's attitudes towards animal research since it may be their closest personal exposure to it.

Animals are amassed in still higher volumes by the US federal government. The mandate of the Food and Drug Administration (FDA) demands that they ensure the safety of food, drugs, and cosmetics for the public; animals mediate the FDA's charter by serving as the first testers of these products. The Department of Defense, too, invests profligately in experimentation. Testing the efficacy of novel weapons systems or psychological reactions to unique wartime circumstances, the Department of Defense goes through vast numbers of animals. Animals are involved in several other departments of agencies, but these will not be discussed here so as not to belabor the point. To summarize, the government engages to a high degree in animal testing.

Albeit not entirely in the purview of this thesis, animal welfare does relate to the topic at hand. Without the concept and advocacy of animal welfare, we would be even more deluded to the numbers and types of animals employed in research than we are today. After some key historical incidents, one of which involved a family pet dog (Pepper) kidnapped from their home

and sold into research (don't mess with a family's pet), reached public awareness, the tide for animal welfare in the lab was indomitable (Brown & Winnicker, 2015). Thereafter, the government passed the federal Animal Welfare Act (AWA) in 1966, establishing basic ethical requirements for researchers operating within the ambit of the federal government. This action by the government placated some advocacy groups, but overall it was quite limited in scope (Bayne & Anderson, 2015).

Estimates of the quantities and types of animals serving as models should be scrutinized extensively. The numbers reported by such agencies as the Department of Agriculture and the US Congress Office of Technology Assessment are dubious for several reasons. First, not all laboratories answer to the government's restrictions (Singer, 2009). Institutions seeking government funding and certain accreditation must adhere to the standards best captured by the *Guide for the Care and Use of Laboratory Animals* (Bayne & Anderson, 2015). This covers most laboratory work, but animals used for instruction, among others, are excluded from the regulations. One annual report from the Department of Agriculture enumerated the most common animal models: "140,471 dogs, 42,27 cats, 51,641 primates, 431,457 guinea pigs, 331,945 hamsters, 459,254 rabbits" (Singer, 2009). While this sums up to approximately one million animals in a given year, the actual total is unknown. The Office of Technology Assessment, cited earlier, proposes that, in reality, the number falls somewhere between ten and one hundred million (Singer, 2009).

Conspicuously missing from the above list is this thesis's protagonist: rats. The reason for the rat's exclusion from the statistics on animal use weaves in with our complicated attitude about them. Unquestionably, rats—as living, oxygen-consuming creatures—are animals. Even so, the rules and regulations of the US don't classify them as such. Per the policy delineated by

the Animal Welfare Act, experiments centered on rats—along with birds, mice, reptiles, frogs, and farm animals—lie outside the jurisdiction of the AWA (Singer, 2009). This dismissal is striking when noting the astronomical number of rat-related experiments in the literature. Experimenters may nevertheless voluntarily report their usage of these aforementioned animals, but the high workload the scientists already endure means that the average, opportunistic experimenter is apt to exploit this loophole and circumvent the tedious paperwork; the forms, as an example, demand that the researchers report the numbers of animals used, in tandem with other information, such as a defense of their use of live animals in the first place and an affirmation that they earnestly considered experimental alternatives to live animals, also known as *in vivo* testing.

Our reliance on animals in the laboratory is contentious, to say the least. Clearly, not all of the above animals arouse moral outrage in everybody; not much emotionally connects humans to rats, for instance, in the same way we feel a visceral companionship with most primates. Primates, at an infinitesimal phylogenetic distance away from us, provide a fairly perceptible mirror into our past; we can, without much strain, see the resemblance and, consequently, we despair at their exploitation in the lab. To many of us, the evolutionary relationship between primates and us suggests that we have much in common, the operative similarities in the realm of research being the capacity for emotion and intellect. Holding that in mind, we regard primate use in the lab as untenable. Rats, however, represent all the things that we are not—at least, that is what we prefer to think. Rather than being humanity's mirror, we want to see them as our counterpoint, the state we would devolve into without civilization. They live in filth, revel in disease, and reproduce with impunity. Rats aren't even animals; they're vermin. This brings us to the present chapter's paradoxical raison d'être: If rats are the antithesis of humanity, then why are

they the scientist's most beloved animal model? Why do they purport to represent all that is human in the lab?

The ascension of the rat

We've discussed at length the rat's assigned role as pest; it's probably their most prominent capacity in the eyes of most. In contrast to that sinister part they play, rats more than make up for it in their laboratory alter ego. In fact, rats, for physiological and behavioral reasons to be discussed later, are so useful in this regard that they have become the standard animal model in most laboratories. The numbers are telling; according to Berdoy (2002), approximately one academic article grounded in research performed on rats is published every hour. On top of its tremendous frequency of use in the lab, rats were also the first mammalian organism bred expressly for experimentation (Kuramoto et al., 2012). This raises the question, which will be explored, of how rats insinuated themselves so firmly and irreversibly in this role.

The exact origin of the first laboratory rats is dubious, but likely invokes a figure briefly discussed in the previous chapter: Jack Black, the royal rat-catcher to the queen. Surely, the travails of trapping rats seem stale to an outsider. Rats have a way of making the job interesting, though. Rat ingenuity in evading capture makes for a compelling back-and-forth between rat and rat-catcher; they must always be one step ahead of the rat, who in turn attempts to be one step ahead of man. Jack Black especially, in addition to the novelty induced by slippery rats, ensured he would never tire of his profession. Aside from the carnivalesque performances discussed in the last chapter, Black also had an eye for beauty—rat beauty.

Sometimes Black sold the rats to the rat baiters discussed in the last chapter. But whenever he spotted a rat with a peculiar coat or texture, he trapped it as he would any other rat. These arguably lucky rats, however, he did not kill. Black, instead, seizing on an economic opportunity, selectively bred these uniquely coated rats to sell to the select few of the London population who, surprisingly, wanted the first pet rats. As reported in Mayhew's (1851) *London Labour and the London Poor*, Black "sold many to ladies for keeping in squirrel cages." These albino and pied rats most likely are the progenitors of today's laboratory rats, too. The rats in the lab, then, are of the very same species as the rats haunting our cities. These lab rats only differ in demeanor and appearance. Albeit descendants of a highly specific genetic line of rats deliberately bred for characteristics such as docility and color, lab rats are nevertheless card-carrying members of the species *Rattus norvegicus.* That's one possible contender for the ancestry of lab rats, but still to be examined is how rats were first incorporated as a fixture of the laboratory. To answer that question, we look to the nineteenth century world of science.

The first animal model

Precisely when scientists grasped the potential offered them by rats as research models continues to confound. That being said, it's likely that the first controlled rat experiment was carried out by Philipeaux, a French physiologist, in 1856 (Lindsey & Baker, 2005). The literature of experiments capitalizing on rats around this time—though dotted with some rat methodologies—remains sparse, suggesting that the rat as model organism still had not swayed the majority of biomedical researchers. Rats would not attain their current ubiquity in the lab until the immigration to America of Swiss pathologist Adolf Meyer towards the end of the nineteenth century (Logan, 2005).

After securing a position in the laboratory of H. H. Donaldson at the newly conceived University of Chicago, Meyer did not hesitate to introduce his colleagues to the albino rats he had brought with him from overseas (Lindsey & Baker, 2005). As part of the Department of Neurology at the university, the first incorporations of the rat in the lab all related to studies of the nervous system. Research psychologists, too, soon discovered the myriad applications of lab rats in their studies. Although still not a nationally employed or recognized research protocol, the laboratory rat was gradually beginning to take shape.

Here the stories of Donaldson and Meyer diverge; the story of the rat follows the former. Transferring from the University of Chicago to the University of Pennsylvania's Wistar Institute, Donaldson—having succumbed to the charm of the rat—brought several pairs of albinos along with him (Lindsey & Baker, 2005). Something about rats must have moved Donaldson to make an about-face in his research so he could explore the rat nervous system, hoping to generalize the results to humans. Along with other attributes, domesticated lab rats were more diminutive, docile, and fertile than their wild counterparts (Edelman, 2002). Their size makes them convenient, not too large as to be unwieldy and not too small as to necessitate a microscope (Galef, 2010). The rat's rapid rate of reproduction facilitates breeding them on a commercial scale. On the docility front, there exists, in fact, research devoted solely to this rat friendliness to the researcher, as is captured by the title of a recent article: "Playful Handling by Caretakers Reduces Fear of Humans in the Laboratory Rat" (Cloutier, Panksepp, & Newberry, 2012). That the laboratory rats are usually albino most likely is only incidental and not, as some might believe, to parallel the stark whiteness of most labs.

Donaldson proceeded to publish over one hundred papers all founded on rat research, popularizing the notion that this creature was fitting as a model. In Donaldson's magnum opus,

*The rat: data and reference tables for the albino rat (*Mus norvegius albinus*) and the Norway rat (*Mus norvegius*)*, he defends his rationale for committing to the rat through a different perspective: He declares his goal is to "emphasize the accepted view that the similarities between mammals having the same food habits tend to be close" (Donaldson, 1924, p. xiv). This hearkens back to Rozin's and Pollan's omnivore's dilemma. With that, among his prolific other publications, Donaldson asserts a link between humans and rats and thus a logic or justification for their use in the lab. On top of Donaldson's research, the prodigious output of other researchers relating to the anatomy, physiology, and behavior of the laboratory rat secured the rat its place in history as *the* model organism, for it is only sensible, once scientists formulated scores of methods, equipment, and literature about the rat, to continue working on this animal rather than shifting the paradigm. These researchers, in effect, ensconced the rat as the standard model organism, a role which would persist unflinchingly to this day.

The adoption of rats in the laboratory setting represented an immense shift in the lives of both rats and humans. For rats, they would no longer immediately be subsumed under the moniker of vermin; now, unwittingly, they could contribute greatly to the sciences. For humans, we now possessed a viable living model which would be standardized into many various stocks, including the Wistar Rat—the strain arduously spearheaded by Donaldson at the University of Pennsylvania—and the Long-Evans hooded rat, mostly albino but with a colored face and stripe extending down its back (Lambert, 2011). For both rats and humans, this new relationship further crystalized our bonds to each other. Indeed, Linsey and Baker (2005) describe this dynamic:

> The story is literally one of ascendancy from the gutter to a place of nobility, for what creature is more lowly than the rat as a wild pest or more noble than the same species that has contributed so much to the advancement of knowledge as the laboratory rat! (p. 2)

Rat, the product

Adopting the rat revolutionized not only neurology and psychology but biomedical research at large, too. As the idea of implementing rats in the lab gained momentum due to the mass of research put out from major institutions like the University of Pennsylvania, the demand for laboratory rats soared. The first intensive and calculated breeding program commenced at the Wistar Institute in Philadelphia (Logan, 2005). Supervised by Donaldson, his colleagues, and their students, the American lab rat wellspring swiftly met the explosion in standardized lab rat demand. These first rats were aptly named the Wistar Rat, the first of a profusion of strains to develop over the next century.

These breeding regimens morphed into an industry, having to meet a national market. Consequently, this process gradually eroded away the rat's previous identity. The market transformed the way that people looked at rats: The lab rat was no longer an animal; rather, it was a product. Now, for the lab rat, the provisions of Darwinian evolution are moot points. Instead of the natural environment dictating which traits will prevail in rat populations, that role has been commandeered by mankind. The whims of experimenters determine which genes are transmitted to posterity and which die out. Scientists can elect for their rats to have a certain color, disorder, or even predispositions to cancer. Perhaps evolution does still rule here, with the caveat that evolutionary fitness is now defined on our terms.

Rats vs humans

The logistics of acquiring rats from mass commercial breeders supports their use; it's convenient. But the practicality of a model organism would swiftly be undermined if the model failed to accurately model the true organism of interest—in this case, us. The answer to the question of the rat's representative prowess (and therefore of their value to the researcher) motivates the present section. To start, rats don't have the sharpest of vision. In fact, to be frank, it is comparatively terrible; their visual acuity (related to the smallest space between two stimuli an animal can perceive) is roughly thirty times weaker than ours (Prusky & Douglas, 2005). In defense of the rats, their other senses (primarily olfactory) compensate for this shortcoming. But this perceptual distinction between rats and humans warrants attention considering our greatest perceptual asset is our vision. At least on the foundation of eyesight, the rat seems an improper choice to model human beings. Luckily—or unluckily depending on the perspective—for the rats, other features render them an excellent fit for the job. Rats can delegate the studies on vision to other animals with keener vision, such as cats and primates.

Rats, additionally, differ from humans in their relationship to the day-night cycle: They're nocturnal (Antle & Mistlberger, 2005). The rat's adaptation to become active at night likely explains their poor vision discussed previously. Without much ambient light, the benefit offered by sharp visual acuity plummets. Though one may believe this disparity in circadian rhythm would disqualify rats from their laboratory standard status, circadian rhythms are malleable, as personal experience demonstrates. Those returning from a distant international flight spanning many time zones know the havoc wreaked by jet lag; the circadian rhythm had adjusted to a different day-night cycle before being thrusted back into the original. This discrepancy is jarring. Rats, similarly, can augment their personal circadian rhythms to match

that of their environment; their internal clock will synchronize with those of the experimenters. The facility with which rats adjust their circadian rhythm further illustrates their great adaptability to changing circumstances.

Aside from discounting potential problems with the use of rats, we can discuss their qualities that make them particularly good candidates for use in the lab. First, they accurately model a wealth of human diseases (Koch, 2005). Particularly, scientists have attained success in modeling the following disease areas in rats: bulimia, anorexia, addiction, oncological, neurological, and cardiovascular (Koch, 2005; Shapiro, 1998). Clearly, at a glance, rats differ substantially from humans, considering their size, shape, and lifestyle. Viewed through a different lens, however, the choice of the rat in the lab is perfectly rational. Rodents compose the largest division of the mammalian order of animals. Predicating our laboratory model on the most representative species of the mammals, the rat is an apt choice. Though ostensibly dissimilar from us, much of what goes on behind the curtain—physiologically—is similar in the rat; that's what binds us together under the taxonomical classification of mammal.

Most arresting of the rat's characteristics, their intellectual acumen continues to astonish researchers to this day. A cursory review of the psychology literature reveals the central role that rats play in probing the concepts of learning and memory. Our use of rats for cognitive studies is telling. While some animals' utility in the lab stops with their basic anatomical and physiological similarities they share with us, rats have demonstrated that their cognitive connections are strikingly similar to ours. After all, it would be insensible to believe that the birth of higher cognitive abilities coincided with the birth of the human species. Even though we've come a long way from viewing animals as automata with no internal life of their own, data from animal intelligence studies astounds us: The rat is "an excellent timekeeper…possesses a high degree of

spatial competence…[and] shows considerable sensitivity to number" (Davis, 1996, p. 292). Some of the more remarkable findings of this cognitive research on rats will be discussed in the following section.

The advent of transgenic mice (mice with foreign genes) and knockout mice (mice with silenced genes) has propelled mice to a higher status among researchers; mice now hold the accolade of most sought-after research model, surpassing rats considerably in numbers (Galef, 2010). This process reflects society's meteoric rise in interest in all things genetic, but this hasn't relegated the rat to an inferior plane. Rats still dominate other domains of study. In other words, while the mouse has increasingly become the standard for microscopic studies of genetics and anatomy (though the rat once owned these provinces, too), the rat still holds the scientific community in its paws when it comes to macroscopic behaviors, such as social interaction and cognition, areas from which we can derive revelations about ourselves. Indeed, the field of behavioral neuroscience captures these domains (Lambert, 2011). Whishaw (1999) summarizes this sentiment:

> Approximately 20 million years ago, at a fork in the evolutionary road at which [the rat] departed from its closest cousin the mouse (*Mus musculus*), it chose the attributes that now makes it favored. The brown rat chose complexity as a survival trait whereas the mouse chose simplicity. The rat became social, intelligent, complex, and skilled, all of which are attributes it shares with humans. (p. 411)

The above overview expresses what makes rats impeccable as models for human disease and behavior. Whether we want to admit it, rats share much in common with us; we can learn from them.

Experiments

We now have a basic understanding of who the rats in the lab are, but equally critical to this account of the laboratory rat is what tests and treatments they are subjected to. Research in many fields hinges upon the rat: psychology, neurology, oncology, and essentially all other objectivist experimental areas. Despite the rat's flourishing in disparate fields of science, we can enumerate a catalog of the archetypal rat-related procedures.

To illustrate, rats most commonly play the part as "guinea pig" for drugs, whether familiar—cocaine and cannabis—or experimental. The quest of pharmaceutical discovery and toxicology is a noble one. Through them, we ascertain which drugs are especially toxic and which are potential therapeutic windfalls. Arguably of most impact is whether a given drug will subjugate its user into a state of compulsive drug-seeking and consumption—addiction (Meyer & Quenzer, 2013). The most popular and useful method for measuring addictive potential, the barometer of addiction, is the self-administration method (Meyer & Quenzer, 2013). The logic of the test invokes operant conditioning, which posits that our behavior is molded by its consequences. A behavior followed by a reward will, in theory, be replicated in order to attain more of the reward—reinforcement. Alternatively, a behavior followed by some penalty will be avoided—punishment. Since a drug of abuse elicits some subjectively rewarding feelings (termed drug reward), the animal taking the drug will seek to replicate the behavior that immediately preceded the positive feelings, which is the actual taking of the drug (Meyer & Quenzer, 2013).

A rat, in a box arranged to inject a pharmacological substance directly into its brain or bloodstream upon pressing a lever, can serve as a model of addiction. The rat, in going about its affairs, will inevitably press the lever in the box (see neophilia). The pressing of the lever

induces the injection of the substance under study. If the substance is rewarding—therefore having the potential for addiction—the rat will press the lever again and again, sometimes ad infinitum. Substances known to be reinforcing (cocaine and opioids) result in this drug-seeking behavior, while substances known not to be (antidepressants and antipsychotics) don't, substantiating the validity and generalizability of this procedure (Meyer & Quenzer, 2013). This paradigm represents the standard method to assess a drug's habit-forming capacity, but an increasing group of researchers has realized that the attendant laboratory conditions are prohibitively reductive; in other words, the rat's surroundings don't emulate that of human beings when given the choice to ingest a drug of abuse.

Unsurprisingly, the lab does not accurately reflect the world it purports to represent. Cold, unadorned, and sterile, the lab aims to be devoid of impurities and confounding variables; this, unfortunately, comes at the cost of good representation of the real world. The early twentieth century cages were stark, steel, and lonely, the rats confined to small spaces and forced to walk and sleep on wire floors. (Lindsey & Baker, 2005). These cages provided a highly artificial environment for the lab rats, one which contrasted sharply with the complex and social world in which they lived as wild rats. Diamond, Krech, and Rosenzweig (1964), among others, discovered that a laboratory environment more harmonious with the rat's native ecology—one teeming with conspecifics and stimulating toys—proved a substantial boon to the rat's health in many spheres. Most compelling among these were the neuroanatomical (and therefore mental) changes effected by the *enriched environments*. The intersection of these enriched environment studies with the pharmacological models discussed earlier led to a provocatively informative study to be discussed next.

Piqued by the apparent discord between the rat's natural and laboratory environments, Canadian psychologist Bruce K. Alexander resolved to parse out the relationship between one's surroundings and one's propensity to engage in maladaptive responses, specifically to take drugs (Alexander, Beyerstein, Hadaway, & Coambs, 1981). Alexander et al. (1981) hypothesized that rats housed in a sort of community living style—free to engage with other rats, interactive toys, and other natural species-specific behavior—would scarcely consume an opioid solution placed in the cage. Conversely, rats in the bleak and uninviting cage environment that typically characterizes the rat's laboratory home would ingest markedly higher volumes of the opioid solution, perhaps as a strategy to cope with their loneliness or boredom. (A caveat: Applying descriptors like these bears the risk of engaging in anthropomorphism.)

Impressively, the outcome of the experiment affirmed the hypothesis; the implications are incredible. The accepted understanding of drugs of abuse is that they are inherently addicting; somehow and somewhere along our evolutionary expedition, we regrettably developed a natural predilection for these drugs. The work of Alexander et al. (1981) challenged this notion. Now, the impact of context, of one's social health, is accorded considerable weight. Sociologically, this research contends that one's social support network is infinitely important for determining outcomes like drug relapse. Similarly, as opposed to designing specific interventions for specific drugs, it may prove more beneficial to moderate the social isolation felt by many today. Though Alexander's research methodology has received some criticism, clearly we can learn a lot from rats.

Scientists have performed scores of experiments on rats testing such cognitive qualities as memory, perception, and reasoning (Barnett, 2001). The presence of these intellectual traits in rats is important to parse because the more cognitive parallels we can draw between rats and

humans, the more appropriate a model rat would be. People may be willing to grant the above characteristics to rats without protest but resist conceding any higher-order thinking we believe truly captures what is to be human. Metacognition—thinking about thinking—however, may not be the exclusive property of the human species. Foote and Crystal (2007) discovered exactly that. Rats, somewhere along the line, evolved the very same trait of metacognition. Just as we can evaluate our own state of knowledge and act accordingly, so too can rats. As strikingly unbelievable as it sounds, the subsequent explanation should allay the skepticism.

In order to assess whether rats display metacognition, Foote and Crystal (2007) taught rats to discriminate the duration of two sounds. On its own, discriminatory tests like these are impressive as they illustrate that rats have some perceptual mastery over their environment and the ability to link real things in the world to arbitrary signs (levers to press or holes to poke with the nose) representing them—perhaps the precursor to the faculty of language. At any rate, once the rats could successfully discriminate these tones by duration, the experimenters added a twist to the scheme: They furnished the rats with the option to decline to even take the test. Foote and Crystal (2007) explain the logic:

> People are sometimes aware of their own cognitive processes. For example, a college student entering a classroom to take a test will often have some knowledge about how she will perform on the test. It is noteworthy that this knowledge (whether accurate or inaccurate) is available *before* the student actually responds to the test questions and obtains feedback about performance. This familiar experience (i.e., knowing that we know or do not know the answer) is easily assessed in humans by requesting verbal reports about our experiences. Of course, this option is not available with nonverbal species…. One approach used to study metacognition in non-humans…is to give the

> animal an option to decline to take a test. Presumably, an animal that knows that it does not know the answer to a test question will decline to take the test. (p. 1)

This knowledge of one's own knowledge denotes metacognition.

In trials where rats had the chance to opt out of the test, Foote and Crystal (2007) found that as the difficulty in discrimination increased—when the duration played was intermediate between the short and long tone—the number of times the rat opted out of the trial increased. The subsequent increase in accuracy when the rats decided to take the discrimination task reflects, too, the rat's correct assessment of its knowledge. This study surely casts doubt on what non-human animals are capable of.

Conclusion

Possibly the most human behavior is altruism. This behavior contains actions performed by an animal that are directed to benefit others, with no effect or even a harmful effect upon oneself. The presence of altruism in us helps to demonstrate our morality, our sense of right and wrong. By extension, if we were to find that other species exhibit altruism, we would have the first kernel of evidence pointing to the existence of morality in non-human animals.

As reported by Bhanoo (2011), one laboratory experiment placed one rat in an open space, inside of which was another rat inside a small cage. The free rat soon discovered it could open the door to release the caged rat. This usually happened. To learn whether rats were truly acting altruistically or if they simply wanted companionship, the experimenters introduced a partition between the two rats; the free rat still released the cage rat. Even when the free rat was given two options, to release the caged rat or to nab a tantalizing piece of chocolate, most rats

chose to release their fellow confined rat; some of the ones that first went for the chocolate chose to save some and then release the caged rat so they could share in the indulgence.

The most we can say from this is that rats appear to act out of altruism. Previously cited research, in addition to entire reams of work not cited, illuminate much that rats can offer us in the way of human discovery. Moreover, this research indicates we have much to learn about the abilities of other species and should revisit some old assumptions about the perhaps arbitrary distinctions we draw between animals and human beings. Increasingly, it appears that less and less separates us from them.

Chapter 3: Part of the Family

The power of film to move us is unassailable. Its power to move us to buy a specific product is likely similar. In 2007, this fear pervaded Germany after the release of Disney-Pixar's *Ratatouille* ("Rat Fad," 2007). Predicting the imminent rise in pet rat adoptions after the critical acclaim received by a movie that depicted rats as cute, culinarily inclined animals, animal welfare activists in Germany decided to take action. They wanted to preempt any regrettable purchases of pet rats for pining children; this pattern of increased pet adoption had been seen following other Disney movies: *101 Dalmatians* and *Finding Nemo* ("Rat Fad", 2007). The same author mentioned the following:

> The Federation for German Animal Lovers issued a series of press releases this week stressing that pet rats are not as cute or as gregarious as their cartoon counterparts. A spokesman said the federation is hoping to head off a rat fad that could lead to a flow of rodents out of pet shops, into children's bedrooms and—after the novelty has passed—back onto the streets of Germany.

The main concern, then, appears to be the release of more rats onto the city streets. This increase in rat population, instead of deriving from the naturally explosive reproductive rate of rats, would descend from human folly. And maybe the German anxiety was valid. Allen (2007) reports that sales of pet rats in Paris following the release of *Ratatouille* rose forty percent, raising the national estimate for pet rat ownership to five million. Why would anybody want a pet rat? Among other things, I seek to answer this question in the present chapter. I begin by offering a definition of pets. Next, I delve into the origins of rats as pets. I then catalog the primary reasons people would adopt a pet rat in light of the abundant negativity typically ascribed to the rat. I

move on to discuss a cultural portrayal of rats that serves to deter people from considering the rat as an adequate companion animal. Finally, I explore other positive cultural attitudes toward rats outside the realm of pets.

The behemoth pet industry

Many of us have terrific, sentimental memories associated with pets, but we'd be hard-pressed to define what a pet is. Pets, according to one historian, "are animals that are allowed in the house, given a name, and never eaten", and to another, "pets are animals we live with that serve no obvious function" (Herzog, 2011, p. 72-73). This does not encompass every case (hence the need for the term *indoor dog*), but it gets the job done.

For the most part, people conjure images of dogs and cats upon thinking about pets. They probably should; according to the American Veterinary Medical Association, 36.5% of American households have a pet dog and 30.4% have a pet cat (n.d.). We know that many exotic pets exist, though, like iguanas, snakes, frogs, turtles, parakeets, goldfish, and, of course, rats. These, however, constitute the minority of pets in the country. The number of households that rats call home, for instance, numbers two orders of magnitude lower than the number for dogs or cats. In fact, it's even fewer than this since the statistics cluster rats with other small rodents into a single category.

Pets are increasingly fusing into full-fledged members of the family. From personal observation, I've noticed a funny trend in pet (mostly dog) pampering: designer clothing, perfumes, and posh grooming. That, in some areas, storefronts leave dog bowls by their doors attests to the exceedingly positive attitude felt towards our pets. Financially, pets warrant the

utmost attention. One anthrozoologist tallied up the expenses pets demand of us and concluded that pet spending far exceeds what we spend on movies, games, and music (Herzog, 2011). To quantify, the American Pet Products Association states that Americans spent $72.56 billion on their pets in 2018 (n.d.). If the metric for care is money spent, we assuredly care about our pets.

Origins of fancy rats

First, recapitulating a historical event broached several times in this thesis, we probably owe the beginning of pet rat ownership to the royal rat catcher to the queen of the nineteenth century, Jack Black. In Mayhew's (1851) profile on Jack Black, he learned that Black spared some of the rats he caught the worst fate. These rats only have their coat to thank for their survival. Black reportedly saved the albino rats he found and bred them in order to perpetuate this desirable trait. He sold these rats to London women of the upper classes, and so began the practice of rat fancy, the keeping of rats as pets. Over time, only the friendlier and cuter—beauty is in the eye of the beholder—of the rats were selected to pass on their genes, resulting in today's pet rat, more affectionately known as the fancy rat. Of course, since these fancy rats can still profitably reproduce with their wild counterparts, they remain members of the same species, *Ratttus norvegicus* (the brown rat).

The first panel to put rats on show display, the National Mouse Club, only did so reluctantly (Ducommun, 2010). Reflecting the general ambivalence felt toward rats, the organization did not change their name to the National Mouse and Rat Club until eleven years after the initial showing in 1901. Nevertheless, throughout effectively the rest of the century,

fancy rat sales did not see tremendous growth. Beginning in the 1990s, though, people came to realize the ease, convenience, and delight of owning a pet rat.

Fancy characteristics

According to rat fanciers, there's a surfeit of reasons to adopt a pet rat, or even five. One touted by many fanciers is their cleanliness. Hanson (2012) delineates the rat's typical self-cleaning procedure:

> Cephalocaudal groom ("CCG"): Grooming sequence of face and body (common to all rodents). The rat starts by licking the paws, then rubs them over the head. This is followed by licking and rubbing the side of the body, the anogenital region, and the tail. The sequence may be anywhere from loosely organized to very stylized, performed in a similar or identical fashion each time.

Rats evidently preoccupy themselves greatly with self-care. Stunningly, rats may spend nearly half of all their waking hours grooming themselves (Lambert, 2011). The association of rats with filth, then, is ironic.

Additionally, potential rat owners have substantially more options for "breeds" than merely the albino rat, most commonly associated with the laboratory (though both pet and laboratory rats are of the same stock). According to Debbie Ducommun (2010), the accepted fancy rat expert, "there are thirty colors, ten patterns, six coat types, and three body forms that can be mixed and matched" (p. 21). From personal experience, however, I can attest that most pet stores only sell solid colored or hooded rats—these are white with a colored face, resembling a hood—and they only sell white and brown colors. The most parsimonious explanation for this

is that most pet stores sell rats principally as snake fodder, so they buy the rats en masse from laboratory suppliers where they can get the most for their dollar; laboratory strains primarily have the albino or hooded (Long-Evans) appearance. For more varieties, one must contact rat breeders. These run more expensive. Further, for those who balk with revulsion at the rat's tail, the Manx rat lacks just that.

Some more benefits include their small size, so they don't take up much space, and their voice level. In fact, one shouldn't hear rats at all. As mentioned in the introduction, most rat communication occurs in the ultrasonic range, outside our hearing. This means there's no need to worry about barking. Another very compelling reason people adopt rats relates to their intelligence. Especially compared to other small mammals—gerbils, hamsters, mice, and guinea pigs—rats excel at learning and memory (Ducommun, 2010). Rat fanciers have found success in teaching rats to respond to their names, to only go to the bathroom in certain portions of their cage, and even to perform some tricks for treats.

Perhaps one of the earliest reasons for the embracing of rats relates to their symbolism. People naturally associate grime, greed, and mischief with rats. One wing of the counterculture noticed this connection and seized the opportunity. The punk ideology's adherents began adopting rats in droves as an act of protest, seeking to stand out among the conformity surrounding them with their rats perched on their shoulders (Beumer, 2014). Society's misfits seamlessly embraced the animal kingdom's misfits.

Furthermore, rats are social animals. For this reason, people tend to adopt rats in pairs at the very least. Their social circle does not stop with the other rats in the cage; rats can form bonds with other species too, namely our own. Rats will form an unflinching bond with their owners, most likely recognizing them by scent, in addition to getting along with the family dog

(Ducommun, 2010). There might not be as much luck with a family cat. Scholars have expressed interest in the bond between humans and rats. One group of researchers concluded that pet store rats that had been played with extensively, as compared to a control group, were more likely to emit high-pitched vocalizations—tantamount to laughing in rats—and to display signs of comfort in human hands (LoFollette, O'Haire, Cloutier, & Gaskill, 2018). The facility with which rats can acclimate to human companionship is startling considering the rat's ecological position as a popular prey species. Instead of fearing us, pet rats display affection for us.

Perhaps the biggest drawback attached to owning a pet rat is their incredibly short life span, which usually ranges from two to two-and-a-half years (Hanson, 2012). Of course, some may see this low-commitment quality of owning a rat as a plus. Moreover, this short lifespan represents a cherished decrease in pet medical bills. In fact, rat care overall is inexpensive. A good cage is the priciest part of the initial investment; food, bedding, and toys cost very little. The rat itself will only set one back around $10. In sum, it seems the most alluring reason to adopt a rat as a pet is convenience. Worrying about noise, shedding, and taking the pet on a walk in the blistering cold dissolve into fiction with rat care.

Wide resistance

Some circles have begun to accept the rat as a remarkable companion animal. The push for acceptance, however, has decidedly been an uphill battle. As is commonly known, once a label is attached to something, it's hard to extricate label from object. Accordingly, pet rat enthusiasts face a host of negative rat stereotypes, ones which they hope to avoid themselves. The current state of affairs suggests that the rat's traditional symbolism is poised to win.

Among my generation, the work which most epitomizes the attitude toward rats is the *Harry Potter* series. One of the principal characters, Ron, has a pet rat (Rowling, 1999). This in itself arouses some shock; book and film characters generally aren't depicted with pet rats, at least not normal ones. As the narrative progresses, the pet rat, Scabbers, appears to the audience to be a surprisingly good and loyal pet. By the third installment of the series, that belief devolves into one of suspicion and then of betrayal. Rowling (1999) reveals the Scabbers was, in reality, a human wizard disguised as a rat for all these years. Far from merely any wizard, Scabbers turns out to be a particularly sinister wizard, one directly involved in the deaths of the protagonist's parents. Though extreme, portrayals like this partially explain most of my generation's hesitation around rats.

Cultural adoration

The bulk of this thesis has discussed rats in relatively unpleasant domains: their pestilence throughout history and their subjugation to scientists in the laboratory. Granted, rats generally evoke feelings of fright or revulsion in onlookers, but this does not hold true for all times and places. For some, rats are the object of worship.

Exemplifying this worship, some Indians hold rats in high regard. Hinduism's god of letters and learning, Ganesha, brought rats out of the pit of resentment. Hindus often pray specifically to Ganesha before commencing any arduous enterprise, as the religion associates him with the creation and removal of obstacles (Langton, 2007). Ganesha, the four-armed, elephant-headed deity, is accompanied by a rat in many portrayals (Barnett, 2001). In some, the encumbered rat even carries Ganesha from place to place on its back. Many Hindu deities travel

with a *vahana*, an animal vehicle, but the relationship between Ganesha and his rat *vahana*, Mooshika, is unique; they're friends (Langton, 2007).

How do Indians evince this praise for rats today? The Karni Mata Temple in Rajasthan, India fully captures this reverence. Most Americans would hesitate to enter this sacred temple, for it teems with rats, which raises the question of why the Indian locals don't act to remove these pests. The rats are left unbothered because it is the rats that the Indians come to see (Spurlock, 2016). Six hundred years old, the temple boasts thousands of images of rats along its walls and columns (Spurlock, 2016). Before long, a visitor would notice an equal number of living rats pulsing throughout the temple. One man who lives near the temple expressed the community's motivating belief: "Twenty-five thousand rats live here…but these are no rat. This is a very holy animal. We call it 'kaba'. So if we die…next life, we become the rats. Rat die, next life, rat becomes man" (Spurlock, 2016). Harboring the belief that the rats originate from reincarnated family members, the community considers it an honor to visit the rats in their temple, paying tributes of food as well. Strikingly, when plague erupted in the country, the temple was spared extermination due to its sanctity (Langton, 2007). Although the temple's rats aren't pets themselves, the community treats them with the attention typically reserved for pets.

Conclusion

In spite of all the negative press they receive, clearly rats invite much affection, too. By no measure are rats scurrying their way to the top of America's list of favorite companion animals, but at least they made the list, albeit somewhere toward the bottom. There is a parallel

universe, however, where rats became one of the world's most beloved animated figures. But Ricky Rat doesn't have the same flow.

Yes, Disney's Mickey Mouse was almost a rat, or at least a rat-like creature (Gould, 2008). The Mickey of today and the Mickey of the early twentieth century might as well be different characters. Early Mickey "was a rambunctious, slightly sadistic fellow" (Gould, 2008, p. 333). Mickey's debut in *Steamboat Willie* presented a radically different character, one who entirely encapsulates the prevailing, timely spirit of slapstick comedy. Mickey treats the other animals around him as if they were inanimate, squeezing a duck to produce a honk, for example. His appearance resembled his demeanor. Compared to today, Mickey appeared more mischievous, rattier.

As time progressed, Disney sought to render Mickey Mouse friendlier. To achieve this, his animators exploited humanity's susceptibility to neoteny, the presence of baby characteristics in older animals (Gould, 2008). Time evolved forward, but Mickey evolved backward. In time, Mickey's eyes and head grew larger compared to his body, his nose protruded less, and his arms and legs thickened. Furthermore, his propensity for mischief waned. This transformation is analogous to the relationship between rats and mice—mice appearing more diminutive and approachable.

In the end, the mouse's set of characteristics triumphed over the rat's in the creation of a children's cartoon character. Not on the same scale, but *Ratatouille* propelled the rat to international stardom; the fervor has dissipated since its release. The rat as pet and other positive portrayals of rats figure into other domains of culture, too. Michael Jackson's song "Ben" outlines one such instance of a harmonious relationship between a boy and his pet rat. Granted, this song accompanied a movie of the same name, which characterizes rats as ruthless serial

killers. (Even so, the rat and his owner remain friends!) Further, *Mrs. Frisby and the Rats of NIMH* presents rats as sage, selfless creatures in possession of highly advanced technology (O'Brien & Bernstein, 1986). Be that as it may, the rat came awfully close to global recognition, not for science and not for pestilence, but for affection.

Concluding Remarks

In exploring three distinct domains of rats, their reach and influence on humanity becomes patently clear. Our first encounters likely date thousands of years back. In this capacity, they probably served no more than as a pest to our forebearers. As *Homo sapiens* evolved under the banner of complexity, so too did our relationship with rats. The last two forms discussed in this thesis—as scientific tool and as companion animal—did not emerge until late in our shared history. Despite the immense temporal gaps spanning these rat manifestations, they all nevertheless concern us today. City rats skulk around our communities, repeatedly pilfering our food and possibly housing some diseases. Lab rats represent man's dominion over nature as we design perfect animal models to meet our scientific specifications, all in the name of discovery. Fancy rats, with our permission, reside in our homes, a meteoric rise from their previous and simultaneous position of disdain. The concurrent occupation of all three of these seemingly discrete identities is astounding.

Even so, these relationships seem here to stay, crystalized into the structure of life's routine. As illustrated earlier, the battle between rats and humans for control of the city appears to have reached a stalemate. Irrespective of the masses of funds the city governments appropriate for rodent extermination, the rats prevail against our most advanced methods. With the exception of the entire province of Alberta, Canada—rats find this climate rather inhospitable—the rat's geographic scope extends as far as humanity's (Ducommun, 2010).

With respect to the laboratory, scientists have developed—in the sense of artificial selection—the most loyal and productive of partners in the laboratory rat. Essentially a homogeneous standard, the lab rat allows precision in both controls and in replication. Granted,

mice numbers have surpassed that of rats in the lab, the rat is still the choice animal model of humankind in experiments calling for any semblance of complexity in behavior. Mice share enough internal processes with us to have value in laboratory investigations, but rat cognition and behavior is far closer to the real thing.

No upward trend in pet rat adoption seems to loom in the future, but their popularity among the select few who enjoy society's rejects—just as city rats enjoy our refuse—appears intact. Smaller mammals like gerbils, hamsters, and mice acquire pet status more often for many children in the US. Easier to care for than dogs and cats, they can imbue responsibility in children as their first pet. Disentangling the loaded history and connotations the rat carries proves harder to do.

The rat's occupation of these three domains is undeniable. But a story from a few years ago illuminates the dynamism of our relationship with rats. Pest, model, friend—these roles make sense and have passed the tests of time. Rats can do more than this, though. Rats can serve, too, in the capacity of defense. Decades of warring in Cambodia have left thousands of undetonated landmines in rural parts of the country (Becker, 2015). Humans are heavy, apt to set off the mine with a misplaced step. Additionally, burdened with their industrial metal detectors, humans move slowly. Rats, on the other hand, weigh very little and evolved a keen sense of smell. Sensing an opportunity, one Belgian non-profit capitalized on these naturally equipped creatures. Accordingly, there are now entire squadrons of trained rats whose sole mission is to sniff out the buried TNT (Becker, 2015). As of 2015, these military rats have cleared over 13,000 subterranean landmines, saving incomprehensible sums of money and preventing immeasurable injuries and fatalities. Historically, rats tended to connote disease, dissolution, and disrepair, leaving a mess in their wake. Now, however, rats are cleaning up after our mess.

References

Alexander, B. K., Beyerstein, B. L., Hadaway, P. F., & Coambs, R. B. (1981). Effect of early and later colony housing on oral ingestion of morphine in rats. *Pharmacology Biochemistry and Behavior*, *15*(4), 571–576. https://doi.org/10.1016/0091-3057(81)90211-2

Allen, P. (2007, October 3). *Ratatouille starts French love affair with rats*. Retrieved from https://www.telegraph.co.uk/news/worldnews/1565126/Ratatouille-starts-French-love-affair-with-rats.html

American Pet Products Association. (n.d.). Pet Industry Market Size & Ownership Statistics. Retrieved from https://www.americanpetproducts.org/press_industrytrends.asp

American Veterinary Medicine Association. (n.d.). U.S. Pet Ownership Statistics. Retrieved from https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx

Antle, M. C., & Mistlberger, R. E. (2005). Evolution. In I. Q. Whishaw & B. Kolb (Eds.), *The Behavior of the Laboratory Rat: A Handbook with Tests* (pp. 3-14). New York, NY: Oxford University Press.

Barnett, S. A. (1975). *The rat: a study in behavior* (Rev. ed). Chicago: University of Chicago Press.

Barnett, S. A. (2001). *The story of rats: their impact on us, and our impact on them*. St. Leonards, N.S.W.; London: Allen & Unwin.

Barnett, S. A. (2005). Ecology. In I. Q. Whishaw & B. Kolb (Eds.), *The Behavior of the Laboratory Rat: A Handbook with Tests* (pp. 3-14). New York, NY: Oxford University Press.

Barun, A., Simberloff, D., Tvrtkovic, N., & Pascal, M. (2011). Impact of the introduced small Indian mongoose (Herpestes auropunctatus) on abundance and activity time of the introduced ship rat (Rattus rattus) and the small mammal community on Adriatic islands, Croatia. *NeoBiota*, *11*(0), 51–61.

Bayne, K., & Anderson, L. C. (2015). Chapter 2 - Laws, Regulations, and Policies Affecting the Use of Laboratory Animals. In J. G. Fox, L. C. Anderson, G. M. Otto, K. R. Pritchett-Corning, & M. T. Whary (Eds.), *Laboratory Animal Medicine (Third Edition)* (pp. 23–42). https://doi.org/10.1016/B978-0-12-409527-4.00002-X

Becker, R. (2015, October 07). Meet the Giant Rats That Are Sniffing out Landmines. Retrieved from https://news.nationalgeographic.com/2015/10/151006-giant-rats-landmines-cambodia-science-animals/

Berdoy, M. (Producer). (2002). *The Laboratory Rat: A Natural History*[Video file]. Retrieved from http://www.ratlife.org/

Beumer, K. (2014). Catching the Rat: Understanding Multiple and Contradictory Human-Rat Relations as Situated Practices. *Society & Animals*, *22*(1), 8–25.

Bhanoo, S. N. (2011, December 9). Observatory: Rats Have Empathy, Study Finds. *The New York Times*. Retrieved from https://www.nytimes.com/2011/12/13/science/observatory-rats-have-empathy-study-finds.html

Bhaumik, S. (2007, December 12). Plague of rats hits Indian state. Retrieved from http://news.bbc.co.uk/2/hi/south_asia/7141067.stm

Boccaccio, G. (2013). *The Decameron* (W. A. Rebhorn, Trans.). New York, NY: W. W. Norton & Company.

Brown, M. J., & Winnicker, C. (2015). Animal Welfare. In *Laboratory Animal Medicine* (pp. 1653–1672). https://doi.org/10.1016/B978-0-12-409527-4.00039-0

Byrne, J. P. (2012). *Encyclopedia of the Black Death*. Santa Barbara, CA: ABC-CLIO. Retrieved from http://link.galegroup.com.ezproxy.lib.utexas.edu/apps/pub/9781598842548/GVRL?u=txshracd2598&sid=GVRL

Capizzi, D., Bertolino, S., & Mortelliti, A. (2014). Rating the rat: global patterns and research priorities in impacts and management of rodent pests. *Mammal Review*, *44*(2), 148–162. https://doi.org/10.1111/mam.12019

Carey, B. (2012, May 31). In Rat Experiment, New Hope for Spine Injuries. *The New York Times*. Retrieved from https://www.nytimes.com/2012/06/01/health/in-rat-experiment-new-hope-for-spine-injuries.html

Cloutier, S., Panksepp, J., & Newberry, R. C. (2012). Playful handling by caretakers reduces fear of humans in the laboratory rat. *Applied Animal Behaviour Science*, *140*(3), 161–171. https://doi.org/10.1016/j.applanim.2012.06.001

Cowan, P. E. (1976). The new object reaction of Rattus rattus: the relative importance of various cues. *Behavioral Biology*, *16*(1), 31–44. https://doi.org/10.1016/S0091-6773(76)91095-6

Davis, H. (1996). Underestimating the rat's intelligence. *Cognitive Brain Research*, *3*(3), 291–298. https://doi.org/10.1016/0926-6410(96)00014-6

Davis, J. M. (2015, October 19). *Urban Wildlife Pests—Part Three: The Question of Co-evolution*. Lecture presented at The University of Texas, Austin.

Diamond, M. C., Krech, D., & Rosenzweig, M. R. (1964). The effects of an enriched environment on the histology of the rat cerebral cortex. *The Journal of Comparative Neurology*,*123*(1), 111-119. doi:10.1002/cne.901230110

Diamond, J. M. (1999). *Guns, germs, and steel: the fates of human societies*. New York: Norton.

Dielenberg, R. A., & McGregor, I. S. (2001). Defensive behavior in rats towards predatory odors: a review. *Neuroscience & Biobehavioral Reviews*, *25*(7), 597–609. https://doi.org/10.1016/S0149-7634(01)00044-6

Donaldson, H. H. (1924). *The rat: data and reference tables for the albino rat (Mus norvegius albinus) and the Norway rat (Mus norvegius)*. Retrieved from http://archive.org/details/ratdatareference00dona

Ducommun, D. (2010). *Rats: practical advice from the expert*. In *Complete Care Made Easy*. Irvine, CA: BowTie Press.

Edelman, B. (2002). 'Rats are people, too!': Rat-human relations re-rated. *Anthropology Today*, *18*(3), 3.

Flegenheimer, M. (2017, December 21). New York City Escalates the War on Rats Once Again. *The New York Times*. Retrieved from https://www.nytimes.com/2015/06/25/nyregion/new-york-city-escalates-the-war-on-rats-once-again.html

Foote, A. L., & Crystal, J. D. (2007). Metacognition in the rat. *Current Biology: 17*(6), 551–555. https://doi.org/10.1016/j.cub.2007.01.061

Galef, B. G. (2010). Norway Rats. In M. D. Breed & J. Moore (Eds.), *Encyclopedia of Animal Behavior* (pp. 573–578). https://doi.org/10.1016/B978-0-08-045337-8.00046-2

Gould, S. J. (2008). A Biological Homage to Mickey Mouse. *Ecotone*,*4*(1-2), 333-340. doi:10.1353/ect.2008.0045

Hanson, A. (2012). Rat Behavior and Biology. Retrieved from http://www.ratbehavior.org/rats.html

Hendrickson, R. (1999). *More cunning than man: a social history of rats and men*. New York: Kensington Books.

Herzog, H. (2011). *Some we love, some we hate, some we eat: why it's so hard to think straight about animals*. New York, NY: Harper Collins Publishers.

Hoffman, L. (2011). "Of a Monstrous Brood": Rats in Robert Browning's "the Pied Piper of Hamelin." *The Journal of Browning Studies; London*, *2*, 66-70,85-86.

Iwaniuk, A. N. (2005). Evolution. In I. Q. Whishaw & B. Kolb (Eds.), *The Behavior of the Laboratory Rat: A Handbook with Tests* (pp. 3-14). New York, NY: Oxford University Press.

Jacob, J., & Tkadlec, E. (2010). Rodent outbreaks in Europe: Dynamics and damage. In G. Singleton, S. Belmain, P. Brown, & B. Hardy (Eds.), *Rodent Outbreaks: Ecology and Impacts* (pp. 207-225). Los Banos, Philippines: International Rice Research Institute.

Jones, H. P., Tershy, B. R., Zavaleta, E. S., Croll, D. A., Keitt, B. S., Finkelstein, M. E., & Howald, G. R. (2008). Severity of the Effects of Invasive Rats on Seabirds: A Global Review. *Conservation Biology*, *22*(1), 16–26. https://doi.org/10.1111/j.1523-1739.2007.00859.x

Kalisch, P. A. (1972). The Black Death in Chinatown: Plague and Politics in San Francisco 1900-1904. *Arizona and the West*, *14*(2), 113–136. Retrieved from JSTOR.

Kazanjian, P. (2012). Frederick Novy and the 1901 San Francisco Plague Commission Investigation. *Clinical Infectious Diseases, 55*(10), 1373–1378. https://doi.org/10.1093/cid/cis693

Kelly, J. (2005). *The great mortality: an intimate history of the Black Death, the most devastating plague of all time* (1st ed). New York: Harper Collins Publishers.

King, R. (Producer). (2009, February 24). Rat Attack [Television series episode]. In *NOVA*. PBS.

Koch, M. A. (2005). Experimental Modeling and Research Methodology. In M. A. Suckow, S. H. Weisbroth, & C. L. Franklin (Eds.), *The Laboratory Rat* (2nd ed., pp. 1-52). Elsevier Science and Technology.

Kuramoto, T., Nakanishi, S., Ochiai, M., Nakagama, H., Voigt, B., & Serikawa, T. (2012). Origins of Albino and Hooded Rats: Implications from Molecular Genetic Analysis across Modern Laboratory Rat Strains. *PLOS ONE*, *7*(8). https://doi.org/10.1371/journal.pone.0043059

LaFollette, M. R., O'Haire, M. E., Cloutier, S., & Gaskill, B. N. (2018). A happier rat pack: The impacts of tickling pet store rats on human-animal interactions and rat welfare. *Applied Animal Behaviour Science*, *203*, 92–102. https://doi.org/10.1016/j.applanim.2018.02.006

Lambert, K. (2011). *The lab rat chronicles: a neuroscientist reveals life lessons from the planet's most successful mammals* (1st ed). New York: Penguin.

Langton, J. (2007). *Rat: how the world's most notorious rodent clawed its way to the top* (1st ed). New York: St. Martin's Press.

Lindsey, J. R., & Baker, H. J. (2005). Historical Foundations. In M. A. Suckow, S. H. Weisbroth, & C. L. Franklin (Eds.), *The Laboratory Rat* (2nd ed., pp. 1-52). Elsevier Science and Technology.

Logan, C. A. (1999). The altered rationale for the choice of a standard animal in experimental psychology: Henry H. Donaldson, Adolf Meyer, and "the" albino rat. *History of Psychology*, *2*(1), 3–24. https://doi.org/10.1037/1093-4510.2.1.3

Logan, C. A. (2005). The legacy of Adolf Meyer's comparative approach: Worcester rats and the strange birth of the animal model. *Integrative Physiological & Behavioral Science*, *40*(4), 169–181. https://doi.org/10.1007/BF02915214

Marris, E. (2019, April). In the City's Shadow: Wherever There Are People There Will Be Rats, Thriving on Our Trash. *National Geographic*, 126-147.

Mayhew, H. (1851). *London Labour and the London Poor* (Vol. 3). Retrieved from http://www.gutenberg.org/files/57060/57060-h/57060-h.htm

Meyer, J. S., & Quenzer, L. F. (2013). *Psychopharmacology: drugs, the brain, and behavior* (2nd ed). Sunderland, Mass: Sinauer Associates.

National Research Council (US) Committee to Update Science, Medicine, and Animals. (2004). *Science, Medicine, and Animals*. In *The National Academies Collection: Reports Funded by National Institutes of Health*. Retrieved from http://www.ncbi.nlm.nih.gov/books/NBK24656/

O'Brien, R. C., & Bernstein, Z. (1986). *Mrs. Frisby and the rats of Nimh* (1st Aladdin ed). New York: Aladdin Books.

O'Brien, S. (2004). Cats. *Current Biology*,*14*(23), 988-989. Retrieved from https://www.sciencedirect.com/.

Panksepp, J. (2007). Neuroevolutionary sources of laughter and social joy: Modeling primal human laughter in laboratory rats. *Behavioural Brain Research, 182*(2), 231–244. https://doi.org/10.1016/j.bbr.2007.02.015

Pest. (n.d.). In *Encyclopaedia Britannica online.* Retrieved from https://www.britannica.com/science/pest-vermin

Pollan, M. (2006). *The omnivore's dilemma: a natural history of four meals*. New York, NY: Penguin Books.

Prusky, G. T., & Douglas, R. M. (2005). Vision. In I. Q. Whishaw & B. Kolb (Eds.), *The Behavior of the Laboratory Rat: A Handbook with Tests* (pp. 3-14). New York, NY: Oxford University Press.

Rajagopalan, R. (2018). A Study In Scarlet. Retrieved from https://www.sciencehistory.org/distillations/magazine/a-study-in-scarletRat Fad: Activists Fear 'Ratatouille' Will Spawn Rodent Craze. (2007, November 13). *Spiegel*. Retrieved from https://www.spiegel.de/international/zeitgeist/rat-fad-activists-fear-ratatouille-will-spawn-rodent-craze-a-517080.html

Rosen, G. (1993). *A history of public health* (Expanded ed). Baltimore: Johns Hopkins University Press.

Rowling, J. K. (1999). *Harry Potter and the prisoner of Azkaban*. London: Bloomsbury.

Shapiro, K. J. (1998). *Animal models of human psychology: critique of science, ethics, and policy*. Seattle: Hogrefe & Huber.

Singer, P. (2009). *Animal liberation: the definitive classic of the animal movement* (Updated ed., 1st Ecco pbk. ed., 1st Harper Perennial ed). New York: Ecco Book/Harper Perennial.

Spurlock, M. (Director). (2016, October 22). *Rats* [Video file]. Retrieved from https://www.netflix.com/title/80136440

Sudarmaji (2010). Rodent impacts in lowland irrigated intensive rice systems in west java, indonesia. In G. Singleton, S. Belmain, P. Brown, & B. Hardy (Eds.), *Rodent Outbreaks:*

Ecology and Impacts (pp. 207-225). Los Banos, Philippines: International Rice Research Institute.

Sullivan, R. (2005). *Rats: Observations on the history and habitat of the citys most unwanted inhabitants*. New York: Bloomsbury Publishing.

Surico, J. (2017, December 22). From the Subways to the Sofa: Pet Rats. *The New York Times*. Retrieved from https://www.nytimes.com/2017/06/08/nyregion/new-yorkers-adopting-rats-as-pets.html

Whishaw, I. Q. (1999). The laboratory rat, the Pied Piper of twentieth century neuroscience. *Brain Research Bulletin, 50*(5), 411. https://doi.org/10.1016/S0361-9230(99)00169-0

Wundram, I. J., & Ruback, R. B. (1986). Urban Rats: Symbol, Symptom and Symbiosis. *Human Organization; Washington, D.C., 45*(3), 212–219.

Yong, E. (2018, July 11). How Rats Remake Coral Reefs. Retrieved April 25, 2019, from The Atlantic website: https://www.theatlantic.com/science/archive/2018/07/how-rats-remake-coral-reefs/564899/

Ziegler, P. (1997). *The Black Death.* Stroud: Sutton.

Biography

Sam Slusky, born in Houston, Texas, is a disciplined Plan II student at the University of Texas at Austin. Along with his Plan II degree, he studies psychology, with the overarching goal of attending medical school after completing his undergraduate studies in 2019. As someone who sincerely values education, Sam spends much of his time teaching, whether that take the form of tutoring friends, volunteering at grade schools, or working as a biochemistry TA. Further, Sam cherishes socializing with others, including members of his own species (friends and family) and members of different species (dogs and rats). Sam is and always will be a lifelong student, his curiosity piqued by topics great and small.